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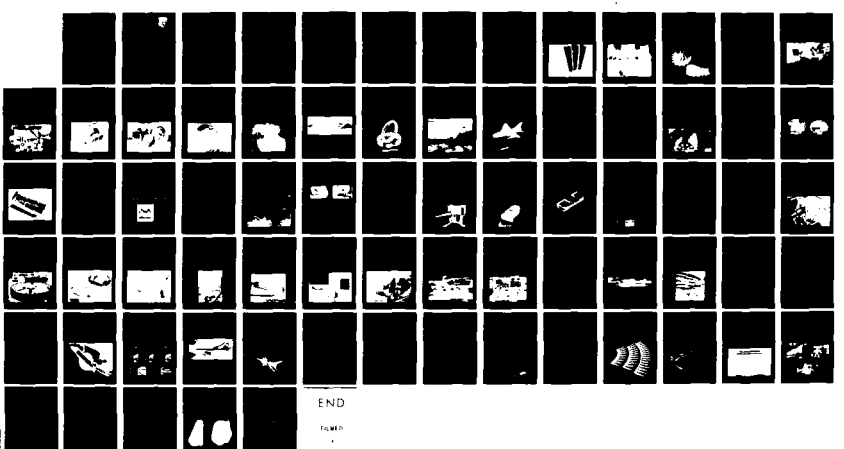

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AFWAL-TR-82-0001

AFWAL FY81 TECHNICAL ACCOMPLISHMENTS

Russell S. Hoff, Jr.

Programs Branch
Plans and Programs Office
Directorate of Management Services

APRIL 1982

FINAL REPORT FOR FISCAL YEAR 1981

Approved for public release; distribution unlimited

AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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Russell S. Hoff Jr

RUSSELL S. HOFF, Jr.
Integrated Programs Group

FOR THE COMMANDER

J. M. KELBLE
Deputy Director of Management Services
AF Wright Aeronautical Laboratories

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This report contains highlights of significant technical achievements made during FY 81. The document exemplifies the broad range of R&D activities being undertaken within AFWAL and the significance of the technological contributions being made to enhance Air Force operational capabilities. The accomplishments have been grouped by Laboratory to assist the reader in understanding the technologies covered. Points of contact have been identified for each accomplishment, if additional information on the subject is desired.

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PREFACE

Although originally established in July 1975, the current Air Force Wright Aeronautical Laboratories (AFWAL) organization has only been functioning as a single Air Force unit under the direction of the AFWAL Commander since January 1980. Comprised of five organizational elements, i.e., the Aero Propulsion Laboratory (PO), the Avionics Laboratory (AA), the Flight Dynamics Laboratory (FI), the Materials Laboratory (ML), and the Directorate of Management Services, AFWAL plans and executes basic research, exploratory development, advanced development, manufacturing technology, and selected engineering development programs in a wide variety of technology areas.

This report is the second annual AFWAL Technical Accomplishments Report and contains accomplishments from all AFWAL Laboratories. The technology developed as a result of these efforts has the potential to enhance future Air Force weapon systems and equipment or to improve producibility and/or reduced life cycle cost. Although the report was prepared by the Programs Branch, acknowledgement is made to all engineers who submitted the initial technical narratives and associated illustrations. Also special recognition is made to Ms. Helen Maxwell for her outstanding editorial contributions. Inquiries regarding individual subjects may be directed to the point of contact listed at the end of each accomplishment. Commercial telephone users should dial the number indicated. Telephone users with access to the Defense Communication System automatic voice switching network (AUTOVON) may dial 78 plus the last five digits. Inquiries made in writing should be addressed to the appropriate Laboratory point of contact. Comments for improving the format of this report are encouraged and should be addressed to:
AFWAL/XRPI (R.S. Hoff)
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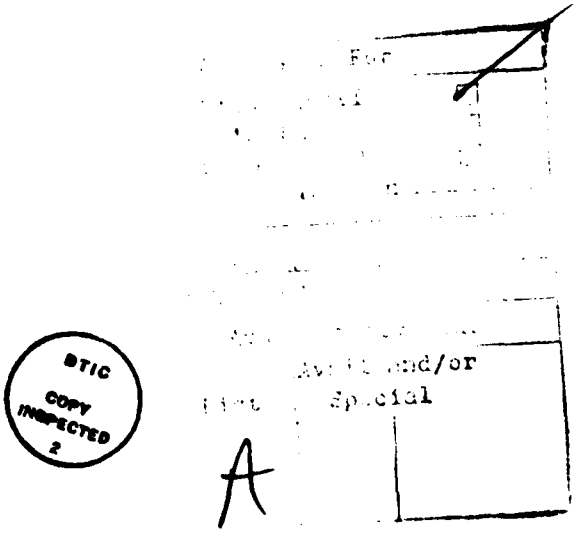

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SECTION I
AERO PROPULSION LABORATORY

TURBINE ENGINE DURABILITY

Several programs have recently been completed to enhance the durability of Air Force turbine engines. One of these efforts resulted in a titanium combustion design model and the development of fire resistant coatings. Over 50 alloys and 25 coatings were evaluated giving designers wide flexibility in material selection for safe and efficient use of lightweight titanium. In a second program, a structural design tool was developed to account for transient overloads due to bird and ice impacts on turbine engine fan/compressor blades. Foreign object damage in aircraft engines has been an ever increasing drain on defense resources and improved design criteria were needed for the newer, more damage-prone blading designs. The new design criteria are based on a 3-D transient structural response tool, and has demonstrated 95% accuracy during F101 engine impact tests. A disk design system has been established which may lead to a fivefold increase in life at a 40% savings in life cycle cost. The system includes damage tolerance criteria, material characterization methodology for crack-growth behavior, design procedures, and analytical life prediction for consideration of large flaws. Using the system, an F100 engine fan disk was redesigned to operate with small fatigue cracks and a design specification was prepared and used in a new MIL-SPEC. The design of very reliable and durable, high performance turbine engines requires accurate definition of the field usage the engine will experience. Engine usage prediction models are being developed by the Air Force, Navy, and industry. The usage prediction models are being validated in part with engine usage data taken from A-10, F-5E, and F-15 aircraft. Establishment of damage related to usage permits the assessment of engine trade-off impacts early in the design cycle resulting in safer longlife engines.

Robert E. Henderson, AFWAL/POT, 513-255-4100

ADVANCES IN TURBINE TECHNOLOGY

Significant improvements in range, thrust-to-weight ratio, reduced cross-sectional area, and number of parts are projected through the demonstration of high-through-flow variable area turbine technology. A turbine rig test successfully demonstrated a 1.5% improvement in turbine efficiency, a design increase of 60% in (AN^2) speed parameter, and durability/lives representative of fighter applications. These advancements will take advantage of variable geometry technology for improved efficiency over a wide range of operating conditions while capitalizing on high-through-flow compressor developments.

Contemporary two-dimensional turbine design procedures do not directly account for endwall and airfoil passage losses/variations which reduce aerodynamic performance. This deficiency has been substantially reduced through the introduction of a three-dimensional viscous flow analysis developed at Airesearch under Air Force sponsorship. Verification of this design tool was carried out in a test which demonstrated a 92% efficiency level (3% greater than conventional designs) in the low aspect ratio turbine.

New heat transfer measurement techniques have recently been demonstrated for turbine engine components which usually rely on cascade type facilities or full scale engine tests. Utilizing full stage rotating hardware, a shock tube and thin-film heat transfer gages have provided point resolution heat transfer measurements and identified an increase of up to 20% in vane heat transfer levels when tested with the rotor vs. the vane alone (see figure). Application of this new experimental capability will permit verification of heat transfer design procedures aimed at increasing engine durability and performance.

William A. Troha, AFWAL/POTC, 513-255-2744

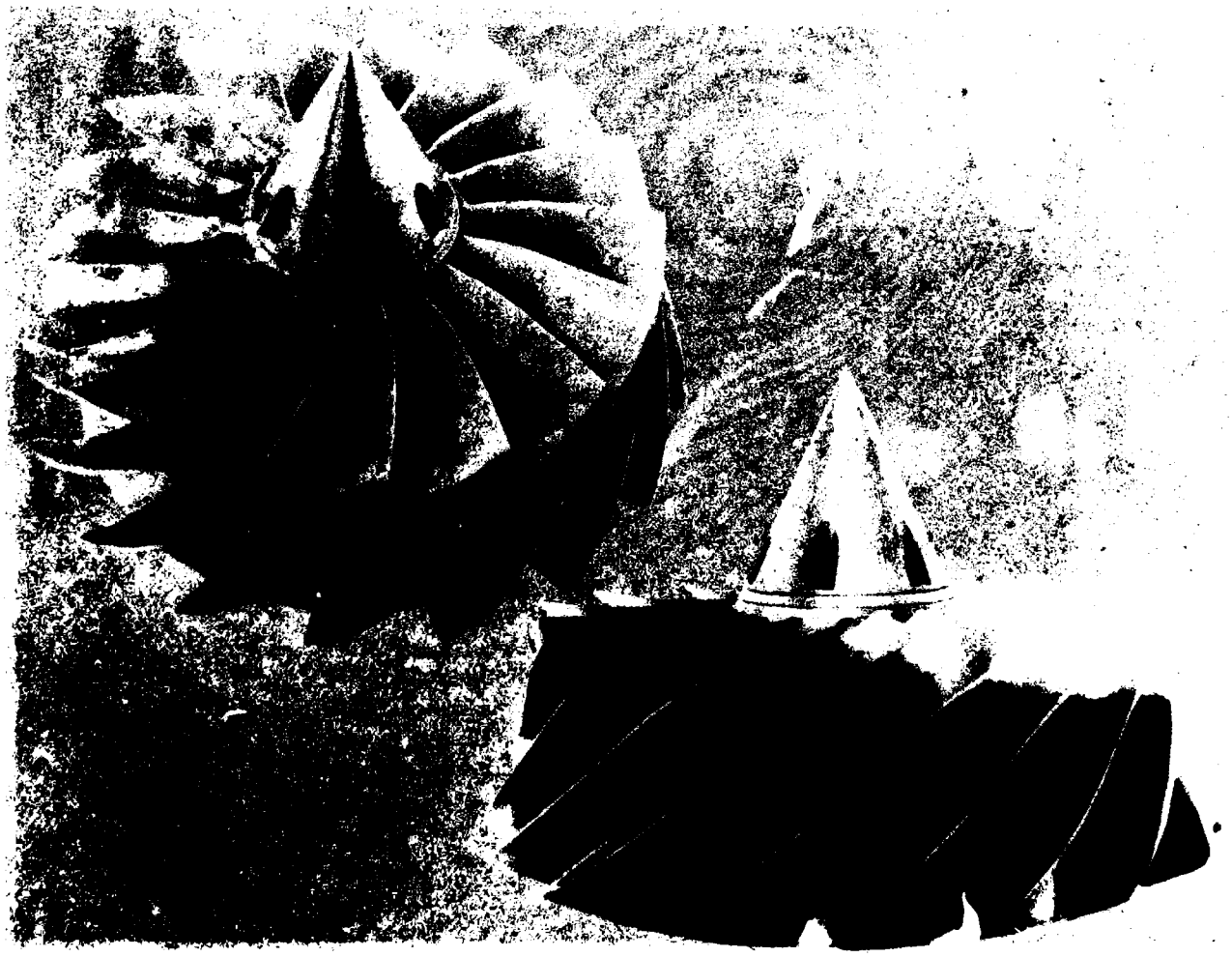
SMALL TURBINE ENGINE DEVELOPMENTS

Advanced technology for small turbine engines is being developed in several areas. In light of current life cycle cost considerations and decreasing fuel reserves, high fuel efficiency is a primary requirement for future small aircraft such as advanced trainers. One recently completed program that resulted in fabrication and test of a 14.5-inch diameter advanced single stage fan designed for high pressure ratio and efficiency could provide up to 50% reduction in fuel consumption over current trainer capability. Test of the fan showed that it met or exceeded all the design goals.

Conventional compressor technology often imposes significant configuration and performance limitations on small engines. Axial compressors offer smaller diameter engines and higher efficiencies while centrifugal designs offer higher pressure ratio per stage. A mixed flow design incorporating the best features of each configuration was recently fabricated and tested. The design efficiency was obtained and the design pressure ratio was exceeded. This technology will be available for future cruise missile propulsion systems and will enhance vehicle performance and survivability (see figure).

Elimination of liquid lubrication systems in advanced small engines offers substantial benefits including reduced weight, lower cost, reduced maintenance, and increased reliability. A program to replace such systems with gas lubricated foil bearings has recently exceeded flight maneuver and gyroscopic load and temperature requirements using a 3.5-inch bearing. This represents a significant step toward the development of gas lubricated bearings for small thrust engines with potential applicability to advanced cruise missiles.

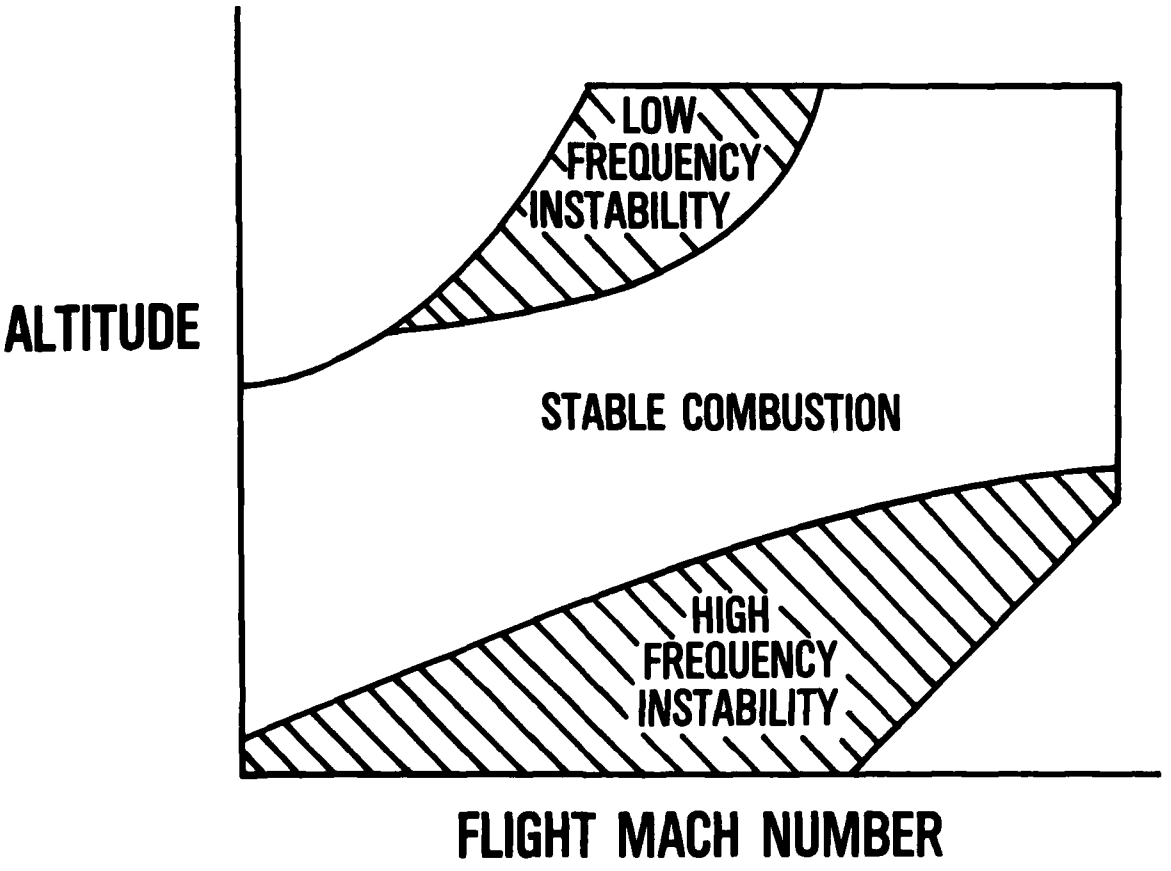
Erik W. Linder, AFWAL/POTA, 513-255-4830



DEVELOPMENTS IN TURBINE ENGINE COMBUSTION SYSTEMS

One of the life limiting components in high performance turbine engines has been the combustion system; however, recent developments in a joint USAF/Navy/Detroit Diesel Allison effort have promised a change. The program has applied Lamilloy™ material technology in transpiration-cooled combustor liners (i.e., the TF41 combuster recently demonstrated 1000 hours of equivalent field service use). The application of Lamilloy™ is expected to more than triple current combustor lifetimes with no increase in liner weight or cost. A variable geometry combustor, which has demonstrated a fuel-air ratio of .004 for lean blowout and .002 for snap decel blowout, is being developed in another joint USAF/Navy/Garrett turbine engine company effort. This technology will significantly improve both the snap decel and altitude ignition performance to high-temperature-rise combustors. Reduction in the time and cost involved in evaluating new combustor designs is now possible using laser techniques. The new in-house capability now permits non-intrusive simultaneous measurements of flame properties and the evaluation of the performance of a wide variety of fuels. An improvement of up to 16% in the thrust-to-weight ratio of high performance turbine engines may soon be possible through the use of carbon-carbon composite exhaust systems. Recent tests in an F100 exhaust nozzle with augmentation successfully demonstrated the capabilities of carbon-carbon divergent nozzle flaps and seals. High strength-to-density ratios and low thermal expansion coefficients characterize these new materials which are expected to reduce augmentor/nozzle weight by 30-40% and increase maximum thrust by eight percent. Operational instability and light-off at high altitude and low Mach numbers (shown in the figure) have been perennial problems with augmented turbofan engines. To help in analyzing these problems, a computer model has been developed at Pratt & Whitney Aircraft. The program has already been applied to the augmentors of the F100 Derivative II and the PW1120 low bypass turbofan engine and future uses are expected to significantly reduce development costs and time.

Robert E. Henderson, AFWAL/POT, 513-255-4100



COMPRESSOR RESEARCH FACILITY CONSTRUCTION COMPLETION

Aero Propulsion Laboratory research and development efforts on turbine engine compression systems have emphasized improving performance and durability while reducing cost and complexity. During the late 60's, it was recognized that more thorough rig testing of compressors and fans would be very beneficial because it would increase our understanding of the internal aerodynamics and reduce the staggering costs of compressor redesigns for operational systems. In addition, problems uncovered in flight, which can slow operational deployment of new engine systems and require flight restrictions, can be resolved.

Construction of the Compressor Research Facility (CRF) was started in 1972 and completed in September 1981. This marks a milestone for the Air Force, since a full-size compressor can be tested to verify performance and to investigate a wide range of research problems. This 30-plus million dollar facility is fully automated both for data acquisition and control and is capable of performing steady state and transient testing.

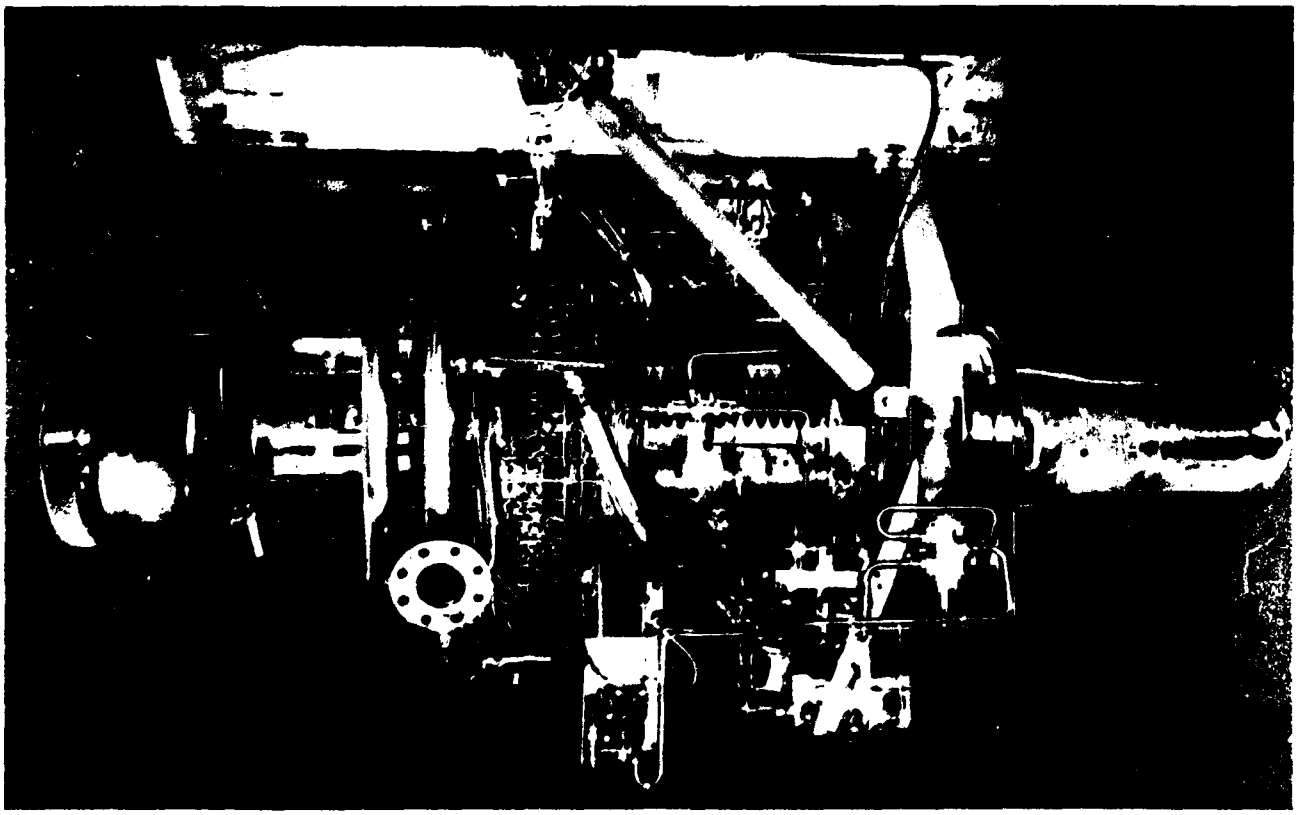
Initial activity includes facility shakedown and test team training and this will be followed by a test schedule which has research and systems support objectives. The first research test will be conducted on a Garrett centrifugal compressor starting in April 1982. This will be followed by a J-85 surface finish research test, a Detroit Diesel Allison ATEGG compressor, and a systems support test on a Pratt and Whitney F100 high compressor. These tests are typical of those planned for the CRF.

Walker H. Mitchell, AFWAL/POTX, 513-255-3904

ADVANCED TURBINE ENGINE GAS GENERATOR AND AIRCRAFT PROPULSION SUBSYSTEM INTEGRATION

In January 1981, the first Advanced Turbine Engine Gas Generator (ATEGG) accelerated life test was successfully completed at General Electric. The GE23 core used in the test was the most durable core ever tested under the ATEGG program, demonstrating the potential for a fourfold improvement in engine durability. The effort revealed the contractor's skill in turbine blade life prediction along with several areas requiring increased attention. The first core engine test of an advanced high-through-flow compressor has been accomplished at Pratt & Whitney Aircraft. The test effort included over 40 intentional compressor stalls to characterize its transient aerodynamic and structural capabilities. This new compressor system can cut the parts/stage count in half while improving durability and performance. The compressor tested exhibited the highest efficiency level to date under the ATEGG program. Improved rotor dynamics in this new generation of "685" core engines (shown in the figure) are due primarily to the advanced squeeze film damped bearing system. Highly successful testing of the GE23 Air Force/ Navy Joint Technical Demonstrator Engine (JTDE) was completed in Feburary 1981. The primary objective was to evaluate advanced variable cycle engine technology and configurations, capable of changing their internal component geometry (and performance) to adapt to changing speeds and altitudes. Variable geometry features change the engine from a supersonic to a subsonic mode of operation for improved performance and fuel consumption over a large part of the flight envelope. The ATEGG program at Teledyne CAE has accomplished a structural assurance cyclic test on the Model 555-2 gas generator with almost twice the test hours and five times the number of cycles ever accomplished at this technology level. In addition, the first core engine demonstration of variable turbine cooling has been achieved. Variable turbine cooling will improve engine durability/performance for future trainers and lightweight fighter aircraft.

Richard E. Quigley, AFWAL/POTP, 513-255-2767
Robert F. Panella, AFWAL/POTP, 513-255-2767



HIGH POWER LEVELS FOR SPACE

Potential future space missions employing high power jamming, space-based radars or directed energy weapons will require very high power levels. Two steps toward providing such power have been taken recently with the demonstration of a superconducting coil and a high power DC-DC converter. In the first of these efforts, General Electric, under Aero Propulsion Laboratory (APL) sponsorship, has achieved a technology breakthrough in superconducting coils for high-power generators. A brittle Nb_3Sn superconducting wire has been statically operated without degradation in a fully potted coil configuration that does not have cooling slots. The coil was "ramped" to the superconducting generator design field without degradation or training and was continuously ramped to 90% of the maximum current and back to zero for 134 cycles without degradation or quenching. The figure shows a 20 MW generator.

The demonstrated capability equals or exceeds all current mission fast-start requirements anticipated for multimegawatt superconducting generators. The demonstrated thermal stability of the potted Nb_3Sn coil also increases the probability of an early successful fast-pulsed inductive energy storage and switching device fabricated entirely from Nb_3Sn.

In a second program, Power Electronics Associates, Incorporated, has developed and delivered a lightweight 200-kilowatt inverter. The inverter converts relatively low voltage (600 volts DC) to 25 kilovolts DC. Using a unique series-resonant concept, the inverter operates at above 95% efficiency. High efficiency is critical for the use of this type of power by the use of lightweight, high-frequency transformers, which were also developed through APL programs.

This specific power is three times better than previously available inverters could provide. It makes feasible the use of several proven low-voltage sources for the high-voltage requirements of space and airborne missions.

Maj Richard D. Franklin, AFWAL/POOS, 513-255-6241

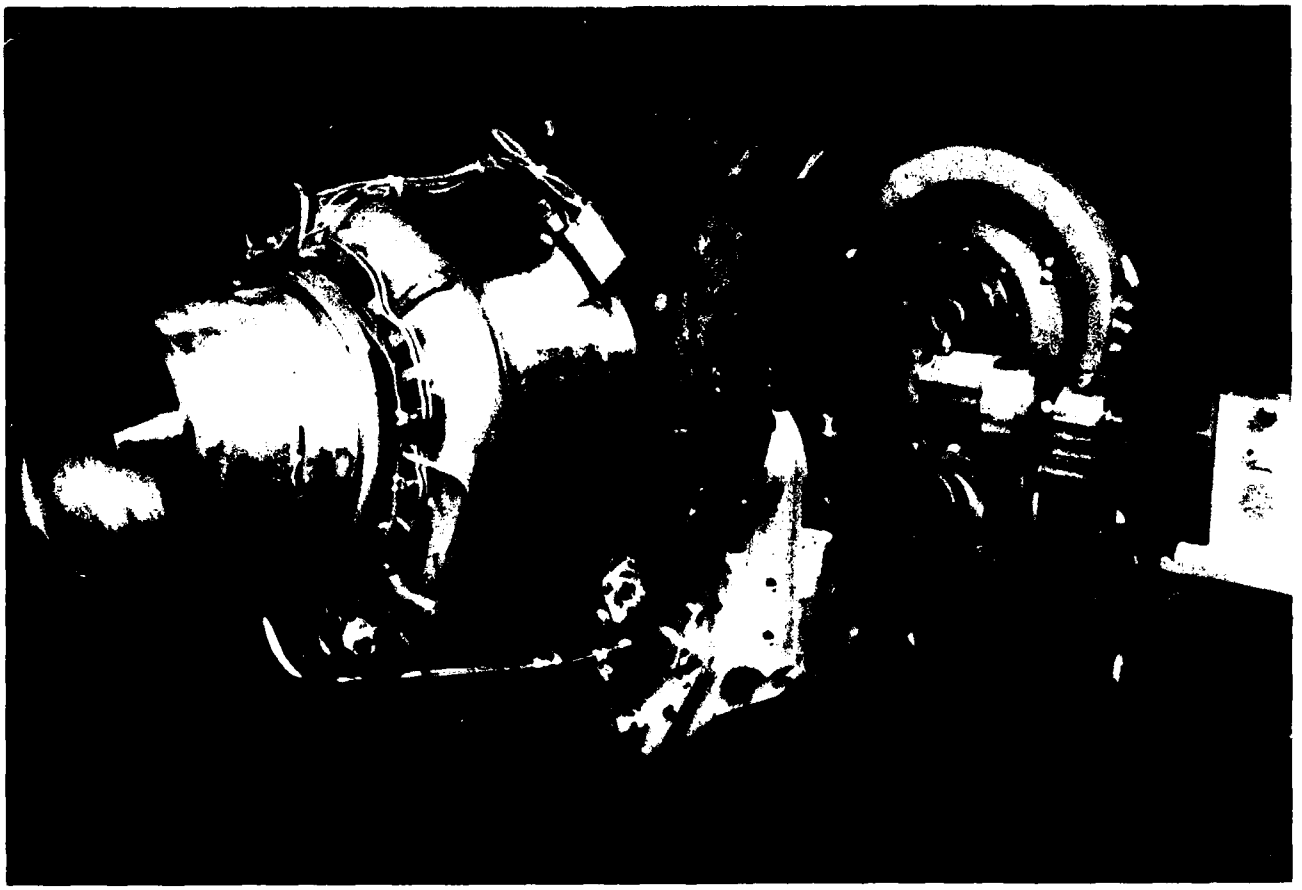
HIGH PERFORMANCE AIRCRAFT AUXILIARY POWER UNIT

Endurance testing has been completed on a new high performance auxiliary power unit (APU) developed for aircraft engine starting and checkout/standby. The extreme simplicity of the modular design in terms of field maintenance was demonstrated along with 50 hours of test time. The unit had a power density of 185 hp/ft^3 and a specific fuel consumption of 0.62 to 0.65 lb/hp-hr. This Avco Lycoming LTS 101 derivative unit provides a new APU alternative for aircraft power.

General Electric under Aero Propulsion Laboratory (APL) contract has designed and fabricated a 60 KVA permanent magnet variable speed constant frequency (VSCF) generator system. The system provides high quality constant frequency electrical power directly from a variable speed source without the need for a hydromechanical unit to drive the generator at a constant speed. The use of permanent magnets results in very high energy density and eliminates the magnetic structure and windings required to produce a wound field excitation. Flight qualification test of a generator (rotating) and a converter (static) revealed that the generator has been overdesigned and is actually in the range of 75 to 90 KVA. The qualification test phase has been completed and eight additional systems will be fabricated to support a one-year service flight test program on two TAC A-10 aircraft.

Fuel pump failures on the F100 engine powering the F-16 aircraft have stimulated development of an emergency backup pump system conceived and demonstrated in-house to provide a "get-home" capability. The system consists of a hydraulic motor driving a standard fuel pump with an emergency throttling valve package. In the event of an engine main fuel pump failure, a detector energizes the motor/pump, which then supplies fuel flow to the engines. A contractual and qualification program are being initiated to implement the emergency system which promises to provide a cost saving of 60 to 80 million dollars.

Maj Richard D. Franklin, AFWAL/POOS, 513-255-6241

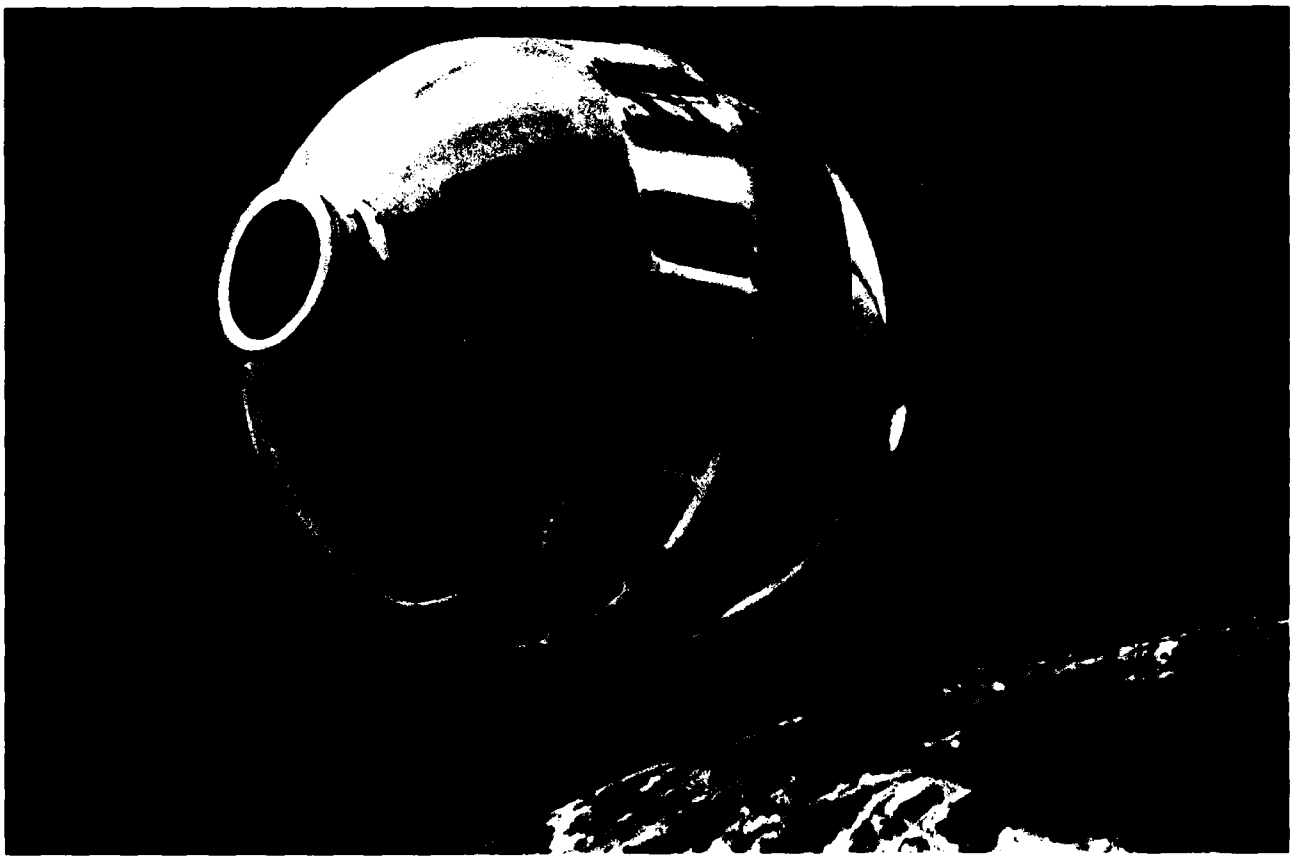


ADVANCED SPACE POWER SYSTEMS

The success of Air Force satellite missions is critically dependent on a long life, reliable source of electrical power. Present satellite missions require solar array areas up to 1200 feet^2 to meet prime power requirements of 10 KW_e. These requirements have been met in the past by silicon solar cell technology, however, Aero Propulsion Laboratory (APL) through contract to Hughes Aircraft Company has developed gallium arsenide (GaAs) solar cells which offer more power, higher efficiency, better radiation resistance, less volume, and the potential of less weight than silicon solar cells. GaAs cells have demonstrated efficiencies of 17% at beginning-of-mission life and 14% at end-of-mission life. The technology has been demonstrated as feasible on the NTS-2 spacecraft and GaAs panels will be substituted for two of the 28 silicon panels on the NASA launched Italian satellite San Marco D/L to be launched in mid 1982. A three-year GaAs Manufacturing Technology Program by the Materials Laboratory is being undertaken to meet the need for an increased production capability by the mid 1980's.

During the past several years, Hughes Aircraft Company under APL contract, has developed and demonstrated nickel-hydogen batteries offering 30% reduction in energy storage subsystem weight for Air Force satellite missions. Specific performance capabilities provided are weight densities of 12 watt hours/pound in low earth orbit (LEO) and 16 watt hours/pound in geostationary orbit (GEO). This technology has been demonstrated on a Space Division Special Projects Office Vehicle and nickel-hydrogen batteries have been selected as the primary power system on the Air Force Satellite Data System Program. This technical achievement of energy storage weight reduction offers increased power or increased satellite payload capability for future space systems. Extension of satellite missions beyond five years in LEO and ten years in GEO is now completely feasible as compared to current mission lifetimes of 3 and 5-7 years, respectively.

Dr. Robert R. Barthelemy, AFWAL/POOC, 513-255-6235



ADVANCED ULTRAVIOLET FIRE DETECTION SYSTEM

Detection is the first, and probably the single most important factor in the control of aircraft engine fires. Current detection technology involves the direct exposure of a wire-like sensor to thermal energy and, therefore, must be located where the fire or overheat is expected to occur. Several significant disadvantages include a high frequency of false alarms estimated as high as 60%, a failure to detect fires in 33% of actual fire incidents, a slow detection and verification response which could allow a fire to propagate beyond control, and a high level of maintenance damage.

To overcome these deficiencies, Aero Propulsion Laboratory (APL) and Aeronautical System Division (ASD), under a contract with General Dynamics, Graviner, Ltd., and HTL Industries, have developed and demonstrated a new radiation-sensitive fire detector system. This system utilizes microprocessor technology to achieve a high degree of flexibility and reliability, which enables the system to detect ultraviolet (UV) radiation from flames and to ignore cosmic radiation, lightning, and other transient conditions. Also, by programming the microprocessor with an automatic self-check and verify feature, the false fire warnings approach 0% and the confidence of detecting all fires approaches 100%. System response time is approximately one second and with the high level of reliability, immediate action can be taken to control a fire. If the system fails, a cockpit warning indicates that the system is incapable of detecting a fire. A memory storage enables maintenance personnel to identify the specific failed components.

This UV fire detection system was installed in each engine bay of an FB-111 aircraft and successfully flight tested for nine months with 35 flight hours and 350 operational hours. Since the capabilities of the microprocessor are highly versatile, the UV fire detection system can be integrated with the conventional overheat systems, thereby increasing the payoff of such a system.

Thomas A. Hogan, AFWAL/POSH, 513-255-4160

FUEL TECHNOLOGY

With rapidly rising petroleum costs coupled with depletion of domestic crude oil and escalation of costly oil imports, potential sources of aviation turbine fuels from shale oil, coal, and tar sands are required. Under Aero Propulsion Laboratory (APL) contracts, three commercial oil refining firms (Sun Oil Company, Ashland Oil Company, and UOP Process Division) have developed satisfactory processing techniques for refining domestic shale into aviation turbine fuel and other finished products. In each case, the processes yielded aviation turbine fuels that meet and, in many cases, exceed current military fuel specifications at prices comparable to fuels produced from petroleum crude oil.

Under APL sponsorship, Sun Oil Company has developed high energy fuels (higher energy content per unit volume) for use in tactical and strategic missiles. The latest fuel, JP-10, was adopted as the specified fuel for ALCM in April 1981. As compared to JP-9, which was previously used in the ALCM, JP-10 provides equivalent missile range and payload, but is superior in terms of safety, ground handling, availability, and storage stability. The current cost of JP-10 is $16/gallon as compared to $50/gallon for JP-9.

Through APL sponsored contracts and in-house programs, major advances in gas chromatography, liquid chromatography, and nuclear magnetic resonance instrumentations have made it possible to analyze complex mixtures such as aviation turbine fuels. These techniques are being applied to the detailed characterization of aviation fuels being used in alternate fuels research programs at APL.

Arthur V. Churchill, AFWAL/POSF, 513-255-5106

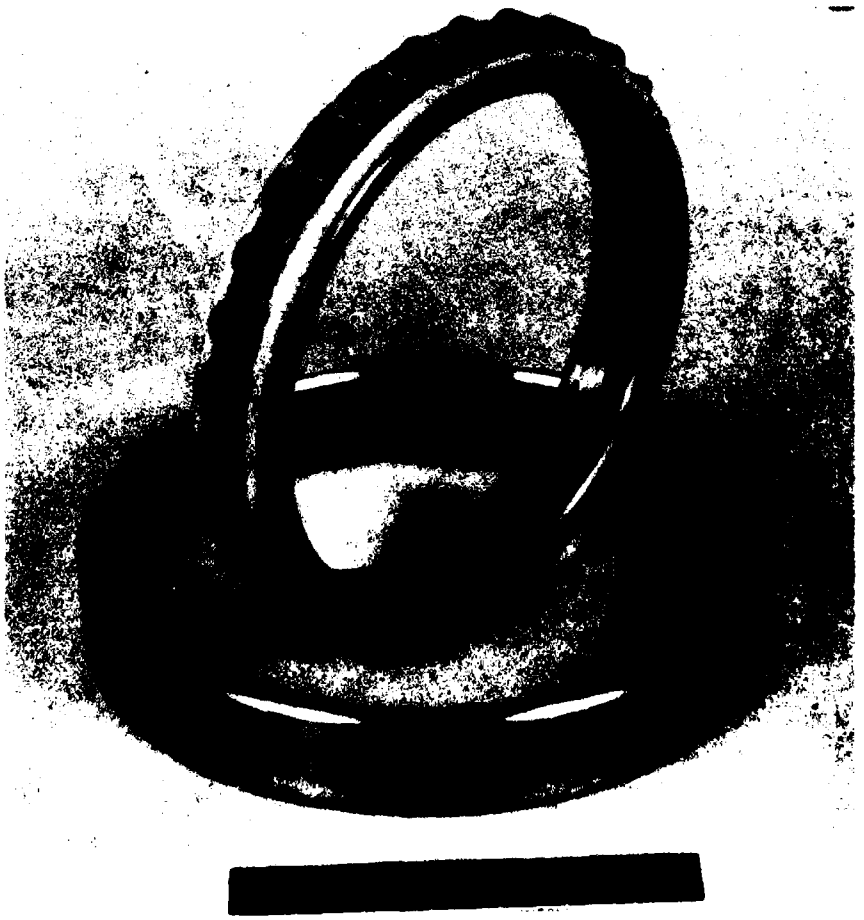
TURBINE ENGINE BEARING TECHNOLOGY

In a program with Pratt and Whitney Aircraft Group, powder metallurgy manufacturing technology has been applied successfully to the production of aircraft-quality engine ball bearings. A prototype powder-processed bearing steel, CRB-7 alloy, was evaluated in full-scale bearing life testing and the results compared to a predicted life for today's standard bearing material, M-50. The bearing design selected was from a current turbine engine (TF33) mainshaft application and 20 of these bearings were successfully fabricated to aircraft quality standards with P/M CRB-7 material. Life results obtained were statistically equivalent to that for conventional M-50. Overall, these results are quite encouraging considering the pioneering nature of this effort. Powder metallurgy technology offers the potential for longer bearing life, lower cost bearings, and reduced use of strategic materials.

It is generally conceded that bearing capabilities in excess of three million DN (bearing bore in mm times rpm) will be required for advanced engines. In developing these capabilities, improved analyses are needed for designing and predicting the performance of bearings operating at these high speeds. In a program with Pratt and Whitney Aircraft Group, a design system was successfully developed for cylindrical roller bearings operating at speeds up to three million DN. The success of this system was demonstrated by the design of a prototype roller bearing (shown in the figure) that successfully completed a 60-hour rig evaluation test. During the test, DN was varied from 2.2 to 3.0 million, with a total of 30 hours at three million DN.

A new technique for monitoring wear of problem bearings has been developed by Pratt and Whitney Aircraft Group, Government Products Division. This technique, to supplement the standard spectrometric oil analysis program, uses low level radioactive tagging of the bearing and monitoring the Iron 55 in the oil.

Ronald D. Dayton, AFWAL/POSL, 513-255-4347



TACTICAL LIQUID FUEL RAMJET DEMONSTRATION

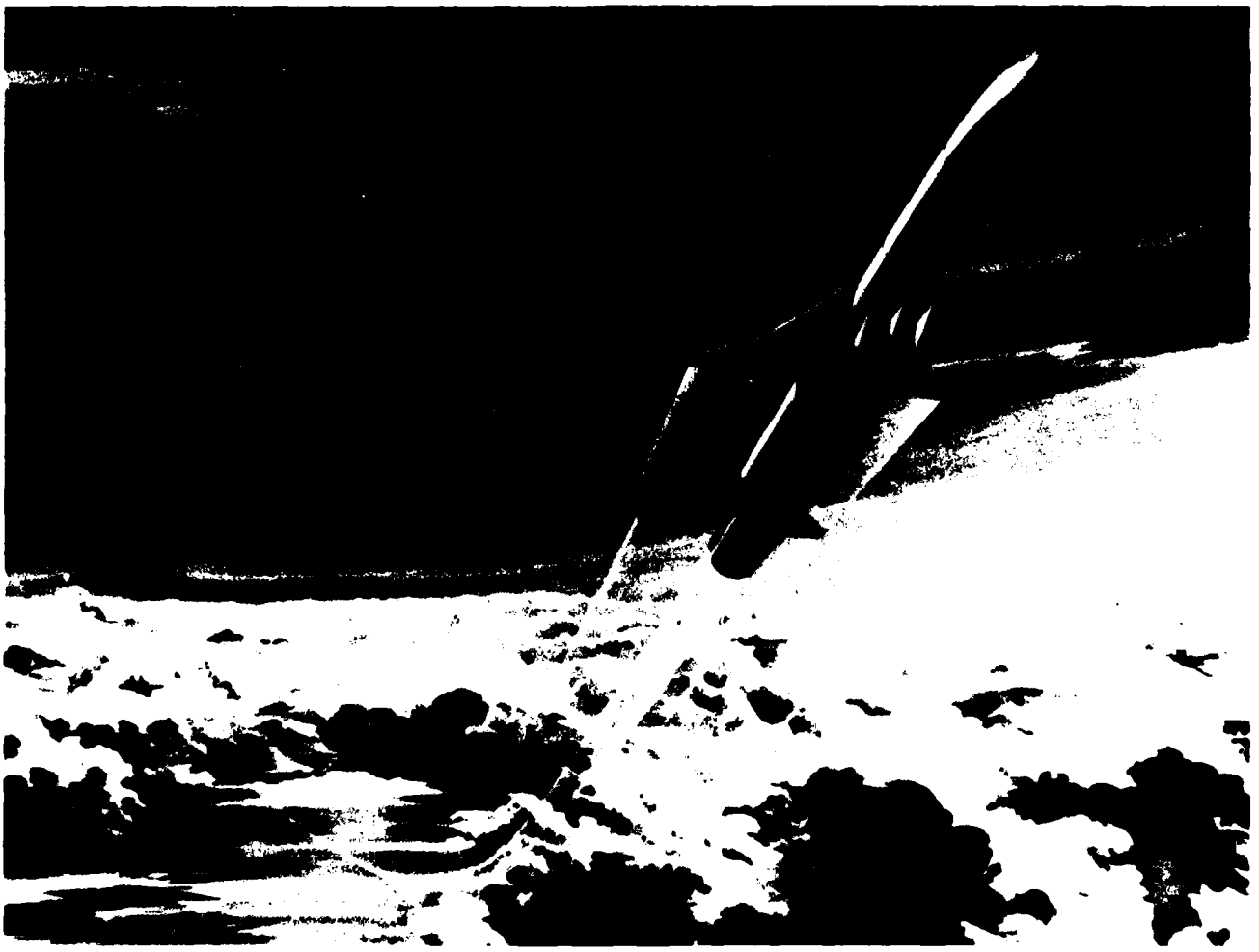
Aero Propulsion Laboratory (APL) has successfully completed the ground demonstration of a liquid-fueled ramjet suitable for providing Phoenix missile range capability in a Sparrow-size missile. The engine design and testing was performed by The Marquardt Company, the prime contractor for the program. McDonnell-Douglas Corporation, as subcontractor, was responsible for the vehicle design and vehicle-propulsion integration activities.

Existing strategic ramjet liquid fuel controls were simplified and scaled down to provide a compact, high turndown ratio throttle. The inlet was basically a two-dimensional design; however, lateral compression by the side walls was a unique feature. Also, a two-dimensional precompression shroud, positioned immediately ahead of the inlet, improved high angle of attack capability. The inlet and fuel control were integrated with an ablatively lined stainless steel ramburner. The resulting extended range ramjet was freejet demonstrated, and a scale model cold-flow engine was wind tunnel integrated with a model of a Sparrow-size missile.

Missile performance, based upon the test results, was calculated to be superior to Phoenix at extended range. The high Mach number, high altitude range objective was met, as well as lower priority objectives.

The Air Force program is complete and the technology is ready for transition to advanced development and preparation for flight evaluation. The Navy is expected to exploit and further develop this technology to provide propulsion for their Advanced Intercept Air-to-Air Missile.

George E. Thompson, AFWAL, PORA, 513-255-5451



ASALM PROPULSION TECHNOLOGY

A significant Aero Propulsion Laboratory (APL) technical effort in missile propulsion has been directed toward the design of a complete integral rocket/ramjet propulsion system satisfying the propulsion requirements of the Advanced Strategic Air-Launched Missile (ASALM), and the demonstration of propulsion system performance at representative ASALM trajectory conditions through a series of engine-component and freejet tests. The technical approach has been the design of an integral rocket/ramjet engine and testing of the component designs through direct connect engine tests. The best configuration was then freejet tested to ascertain integrated system performance. Two competitive designs were evaluated under separate contracts. The Chemical Systems Division's design is responsive to the McDonnell missile airframe configuration while The Marquardt Company's design is responsive to the Martin-Marietta configuration. The technical effort on both contracts has been completed and both designs have successfully demonstrated performance over the whole flight envelope. The technology developed under these contracts will be available for use after the Aeronautical Systems Division (ASD) counter-SUAWACS study is completed and futher direction is given.

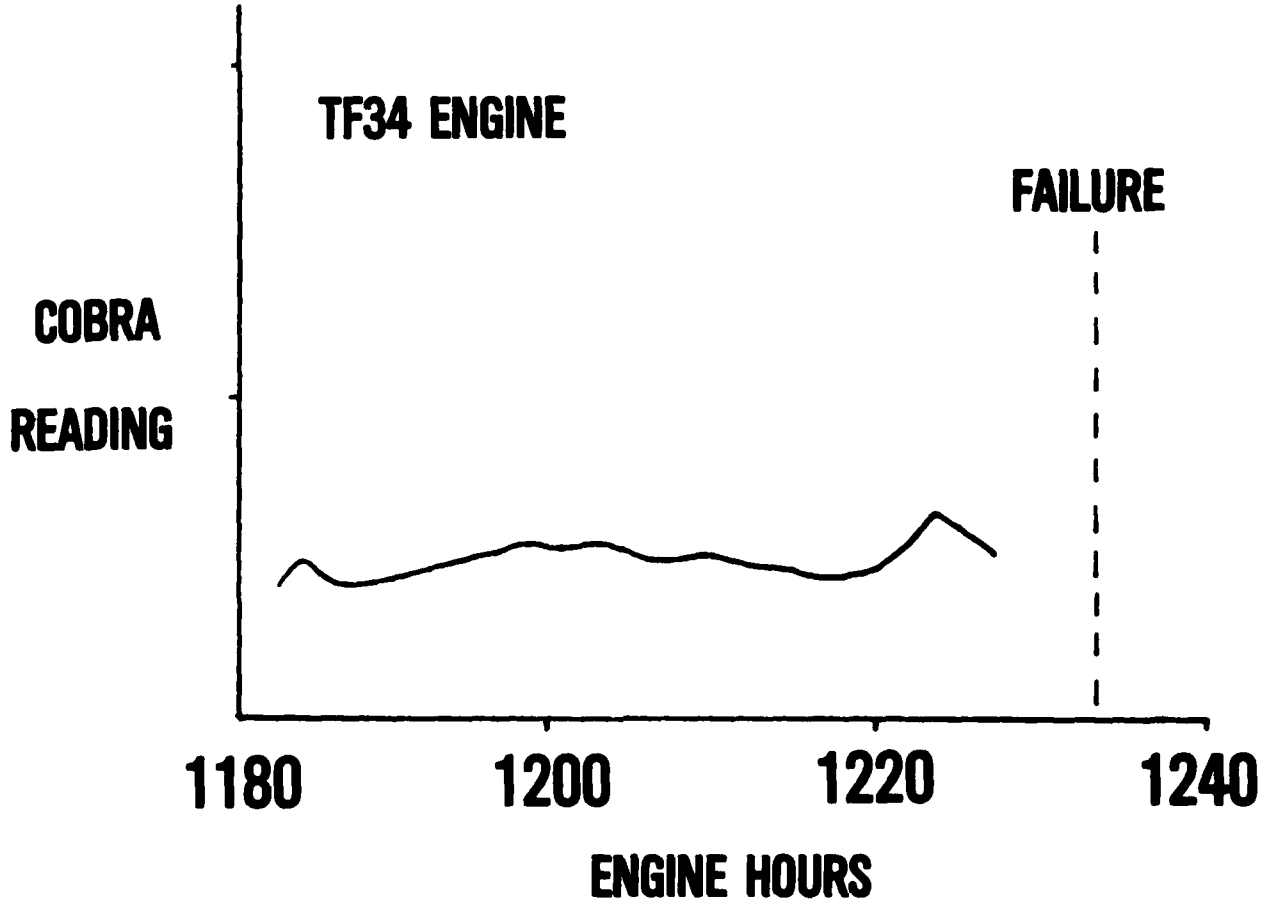
The Laboratory also provided technical support of an ASD managed flight test program on the integral rocket/ramjet. In the flight tests, the maturity of integral rocket/ramjet propulsion systems was demonstrated for an ASALM missile. The technology developed is available for such weapon systems as an SRAM replacement having twice the low altitude range plus the capability of low level launch, high altitude cruise, followed by a low level run-in. This ASALM technology is also applicable to a counter-SUAWACS missile or a multi-mission strategic missile having both air-to-air and air-to-ground capabilities. In addition to providing for an extended range SRAM size missile, the technology can also be used to provide a greater number of missiles (up to two for one) in the same SRAM volume and still exceed the current SRAM flight range.

George F. Thompson, AFWAL, PORA, 513-255-5451

Following a number of seal failures in the TF34 engine on A-10 aircraft, Aero Propulsion Laboratory (APL) scientists have found that incipient failure can be reliably pinpointed by means of the Complete Oil Breakdown Rate Analyzer (COBRA) instrument. This device is extremely simple and economical to operate, requiring less than one minute and no special equipment or personnel training. To date, COBRA has given 24 positive indications of impending seal failure in the TF34 engine. In each case, teardown of the engine has shown that a failure was imminent and that the COBRA prediction was correct. The routine maintenance procedure for checking the seal condition on the TF34 requires eight man-hours, and does not always give an accurate indication of sump seal condition. Furthermore, seal failure typically happens suddenly and the normal 100-hour inspection cycle is therefore inadequate to identify this type of failure. Near-continuous COBRA monitoring, on the other hand, has already been shown to be both adequate and reliable. COBRA is now being field tested with the J75 engine using a new high performance oil on board the F-106. In the near future, COBRA will be used to monitor the J75 operating with routine oils, as well as engines on the C-141 and C-130 aircraft.

Engine designers rely on design guides for the development of high-speed turbomachinery, and for predicting rotor-bearing critical speeds, unbalance response, and rotor stability margin. The previous Design Guide Series, published in the 1960s, has been extremely valuable in this regard, but parts have become nearly obsolete because of subsequent rapid technological developments. To bridge this gap, a nine-volume compilation, "Rotor-Bearing Dynamics Technology Design Guide Series", has been prepared. Topics covered in the series range from flexible rotor dynamics to high-speed tapered roller bearings and foil-type gas bearings, along with design information for ball bearings, roller bearings, and fluid film bearings.

Howard F. Jones, AFWAL/POSL, 513-255-4939



SECTION II
AVIONICS LABORATORY

GLOBAL POSITIONING SYSTEM NULL STEERING ANTENNA

The Null Steering Antenna (NSA) developed for the Global Positioning System (GPS) has been a major highly successful AFWAL Avionics Laboratory effort. The NSA was developed to provide high anti-jam technology capability necessary for GPS user equipment to continue to function fully in intensive hostile electromagnetic environments. The antenna system was designed primarily for application on high performance tactical aircraft and has undergone extensive laboratory and flight tests against multiple jamming sources with outstanding performance results.

The achievement objectives of the NSA program include the development of an adaptive array antenna whose performance, size, and cost characteristics met the need of GPS equipped high-performance aircraft. The technology advancements achieved and demonstrated in the laboratory and flight test program are:

First null steering adaptive array antenna to demonstrate anti-jam protection against multiple jammers with diverse modulations while receiving satellite GPS signals.

Development of a small (10″ × 10″) array applicable to F-16 aircraft. Development of real-time adaptive antenna algorithms including pattern search techniques.

Initial flight operation of a Null Steer adaptive array having excellent satellite coverage, signal fidelity, and navigation accuracy in both ECM and non-ECM environments.

Avionics Laboratory development of the GPS Null Steering Antenna represents a significant achievement for the Air Force. The NSA will play a major role in permitting high-performance tactical, cargo, and strategic aircraft and other users to navigate with the GPS system while operating in intense jamming environments. The NSA's unsurpassed anti-jam capabilities are designed to allow Air Force vehicles having GPS receivers to obtain maximum position and velocity accuracy in an intense ECM environment and to provide highly accurate weapon delivery or cargo drop capability. NSA technology has been transferred to the GPS Joint Program Office as a major risk reduction for their Phase IIB User Equipment Full Scale Engineering Development Programs. In summary, the successful completion of the NSA program and development of the first-generation F-16 conformal antenna array has proven that NSA concepts will significantly enhance the mission effectiveness of the Global Positioning System in intense jamming environments.

James E. Jones, AFWAL/AAAN-2, 513-255-5668

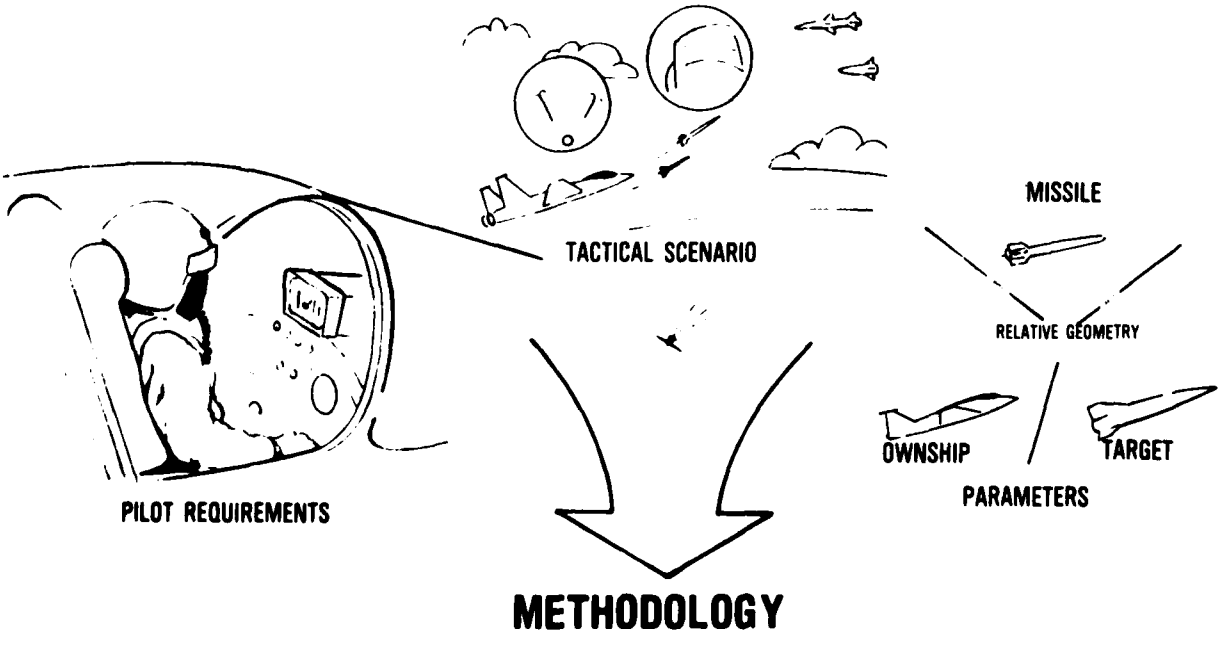
ADVANCED MISSILE LAUNCH ENVELOPE ALGORITHM DEVELOPMENT

The MISVAL program has involved the development of missile launch envelope (MLE) algorithms from initial concept definition through real-time ground simulation and flight test. Basic goals of the program are to decrease the number of out-of-bounds and missed opportunity shots due to inaccurate MLE generation and display techniques, give the pilot engagement trend information in the pre-launch mode, generate accurate post-launch time until missile impact, and predict missile failure due to target maneuver after launch. Current operational airborne MLE algorithms provide maximum and minimum launch ranges for non-maneuvering air-to-air targets only. The MLE algorithms developed in the MISVAL program show an accuracy improvement of 25-500% over current algorithms for maximum range computations. The lower percentage represents an average improvement for co-altitude launches against a non-maneuvering target while the higher percentage occurs in look-up/look-down engagements where current algorithms have little capability. The MISVAL developed algorithms offer not only range indications, but engagement trend information such as time to maximum range when outside the MLE, missile flyout time, and an indication of target maneuver required to defeat the attacker's missile. New post-launch cues include accurate missile time of flight and an indication of predicted missile failure, both updated with actual target track. These latter cues take on additional importance in a multiple target environment when the pilot will have to determine the feasibility of continuing support of an in-flight missile, pressing in for an immediate reattack, or breaking of the engagement for a more lucrative target.

The advanced MLE algorithms have also advanced the state of the art in the algorithm design area. The heart of the new algorithms is a faster-than-real time simulated missile flyout coupled with actual target track to give an accurate indication of missile capabilities. The modular nature of the new algorithms allow for versatility in accepting new air-to-air missile or updated versions of current missiles. Extensive piloted simulations (with the software running in the F-15 or F-16 central computer) and flight test of one of the algorithms have provided pilot inputs into display development. Pilot acceptance of the new algorithms and display concepts has been very high.

The MISVAL program has enhanced the state of the art in air-to-air missile fire control. By replacing pilot's "rules of thumb" with accurate engagement trend information cues, the pilot's ability to manage a tactical engagement is greatly enhanced, with the result being quality missile launches and higher kill probabilities. Some modifications of current missile algorithms and displays have been incorporated into the F-15 and F-16 as a result of work performed in the MISVAL program. The MISVAL program has developed MLE algorithms which are ready for use today as single target/single shot algorithms, and form the basis of future multi-target/multi-shot algorithm development.

Capt Vincent L. Albert, AFWAL/AART-2, 513-255-2713

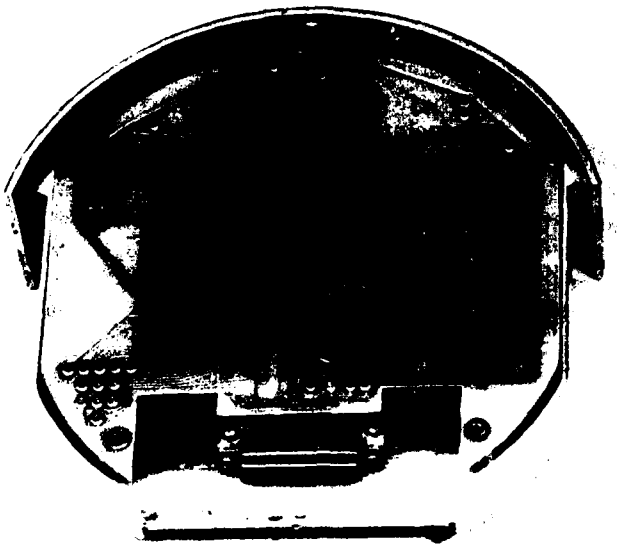


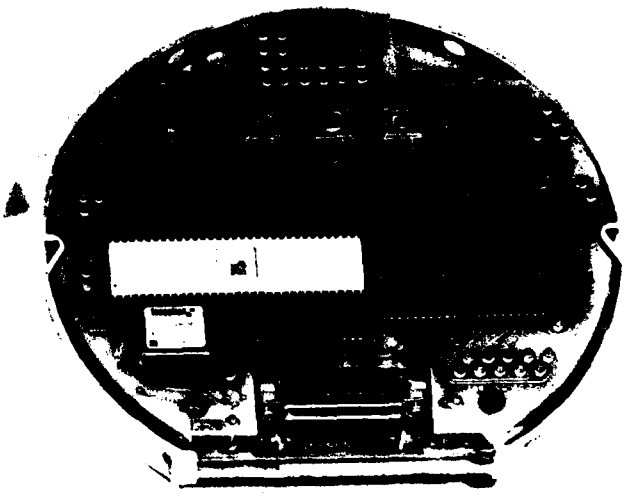
CM-HARDENED ADVANCED OPTRONIC SEEKER

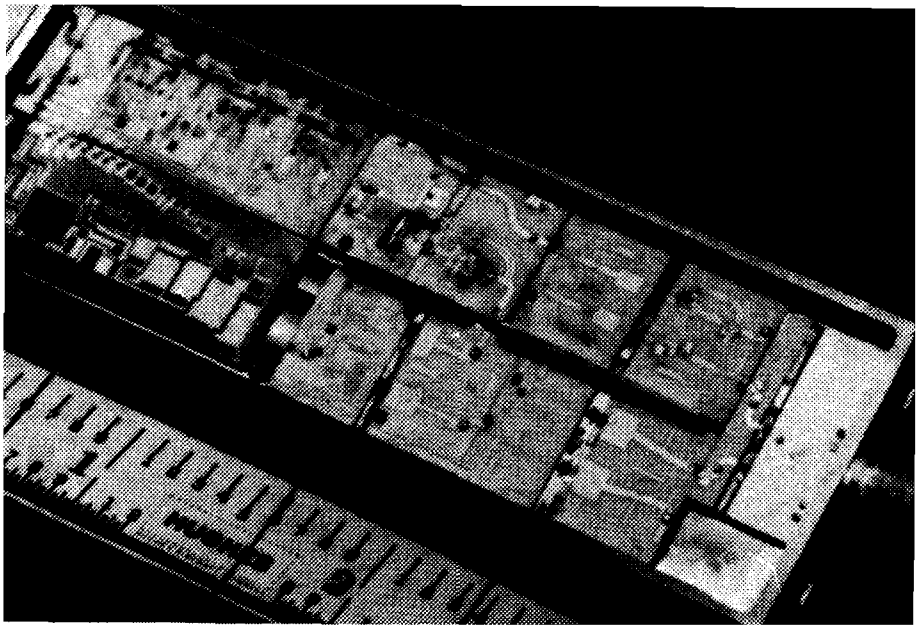
Under Avionics Laboratory sponsorship, Systems Research Laboratory has developed an advanced, CM-hardened, laser seeker (CHAOS). CHAOS has demonstrated significant improvement in CM-hardening the Pave Way II Laser Guided Bomb (LGB) in a plug-in package compatible with both the LGB and the Low Level Laser Guided Bomb (LLLGB). CHAOS incorporates a new coding scheme and CM resistant processing circuitry. Of particular interest, is the use of a microprocessor to implement the coding techniques. Using a microprocessor increases the flexibility and adaptability to counter future threats. The CHAOS microprocessor software control provides: (a) an intelligent search and discrimination capability to find a target veiled by complex CM's, (b) an extremely effective and uninterruptable guidance to target, (c) adaptability to discriminate against CM threats of the future, (d) closer to one bomb, one target philosophy of warfare, and most of all (e) extended lifetime effectiveness for existing arsenal ordnance.

Although the circuitry involved in CHAOS was designed specifically for Pave Way II, the basic CM technique is applicable to other laser seekers. The new LLLGB effort, Laser Maverick, the Army's Hellfire, or any 1.06 laser seeker that produces master triggers after the video detector preamplifiers are candidates for CHAOS technology. The CHAOS digital circuitry can be reduced substantially in size and cost by the use of custom made integrated circuits. The cost of having CHAOS CM-hardening in a laser seeker is about the same cost (in large quantities) as a standard laser seeker.

Jan M. Servaites, AFWAL/AARI-1, 513-255-5292







IR ATMOSPHERIC TRANSMISSION MEASUREMENTS

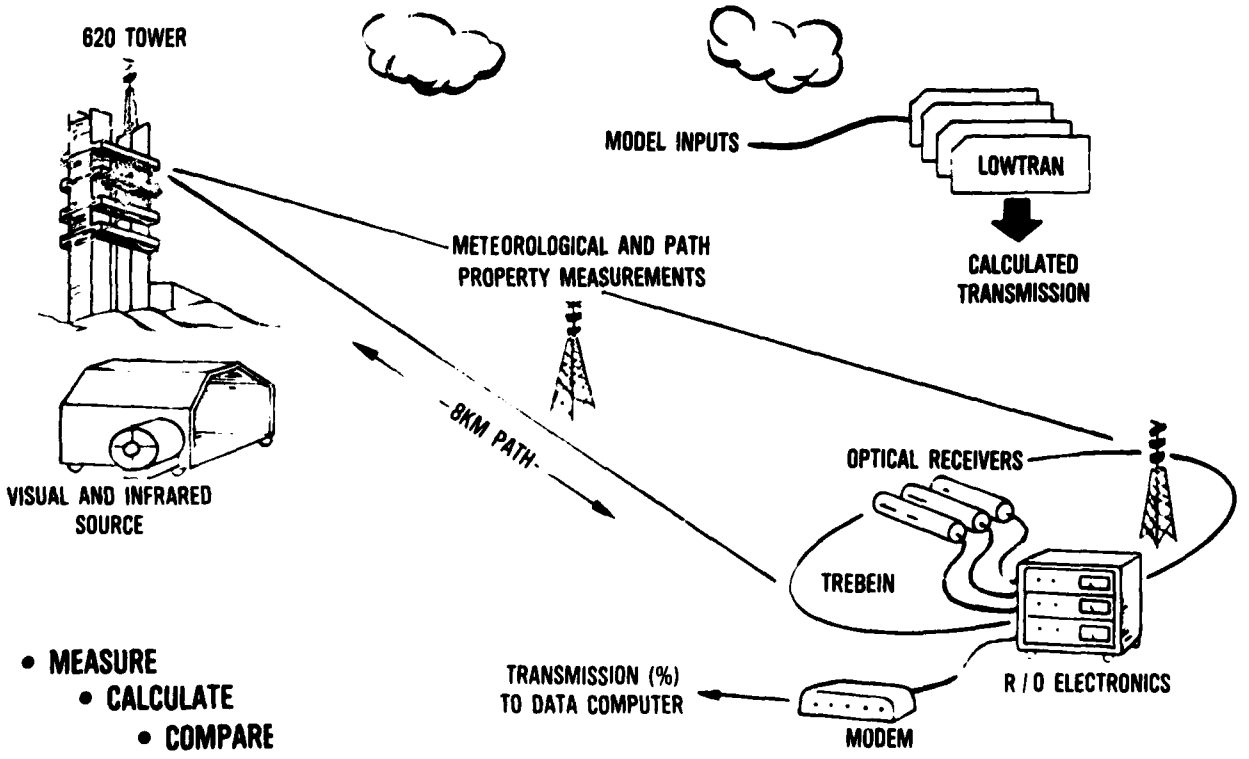
The ability to understand and predict atmospheric transmission is fundamental to successful operational deployment of IR weapon systems. The DOD plan for atmospheric R&D, formulated by OUSDRE, has a technical goal to provide a capability by 1984 to measure, model, and predict accurately the atmospheric transmission effects on DOD sensor and communication systems.

The LOWTRAN computer model is most often used when predictions based on general atmospheric transmission conditions are needed. This model has never been completely validated by experimental measurements taken over long horizontal paths and over the full IR spectrum (3 through 14 micrometers) of interest to the Air Force. Test instrumentation has not been available to make these measurements. The Avionics Laboratory tried to make the measurements but failed. Commercial transmissometers were evaluated and found inadequate. No such instrument was available, even as a one-of-a-kind device, in academia or the atmospheric research community. The need for LOWTRAN model validation was clearly needed.

The Laboratory undertook the in-house development of a broadband IR atmospheric transmissometer specifically designed to validate LOWTRAN over the full electro-optical spectrum, over an 8 km path in adverse weather conditions. On 7 May 1981, the device was successfully demonstrated for the first time in both the 3-5 and 8-14 micrometer IR bands.

The transmissometer has been operated over an 8 Km path in clear weather and bad weather with excellent results. A significant disagreement with LOWTRAN was found in the 4.4-5.3 micrometer region. The Air Force Geophysics Laboratory has modified LOWTRAN to conform to the measurements. Most of the work to validate LOWTRAN remains to be done. The large problems in atmospheric transmission modeling are: the effect of aerosols, the role of visibility in predicting IR transmission, and the relationship of standard meterological observables to IR transmission. A comprehensive measurement program is currently under way in the Targeting Systems Characterization Facility aimed at providing data to resolve these questions. The broadband transmissometer atmospheric transmission measurements are compared to LOWTRAN predictions. Supporting atmospheric physics and meteorological data are provided by the Targeting Systems Characterization Facility. The effort is totally in-house and conducted by Air Force personnel.

Maj Robert L. Johnson, AFWAL/AARI, 513-255-6144



PARATUNE TRANSMIT FILTER

The Paratune Transmit Filter is designed to reduce the broadband noise and spurious signals from a UHF transmitter. It accomplishes this by phase locking a very clean oscillator to a sample of the transmit energy while the remainder of the transmit power is dumped into a dummy load. The filter strips the modulation off the original signal and remodulates the clean oscillator at a high power level (5 to 10 watts). The modulated output is then amplified back up to the desired transmit level of 100 watts or 1000 watts.

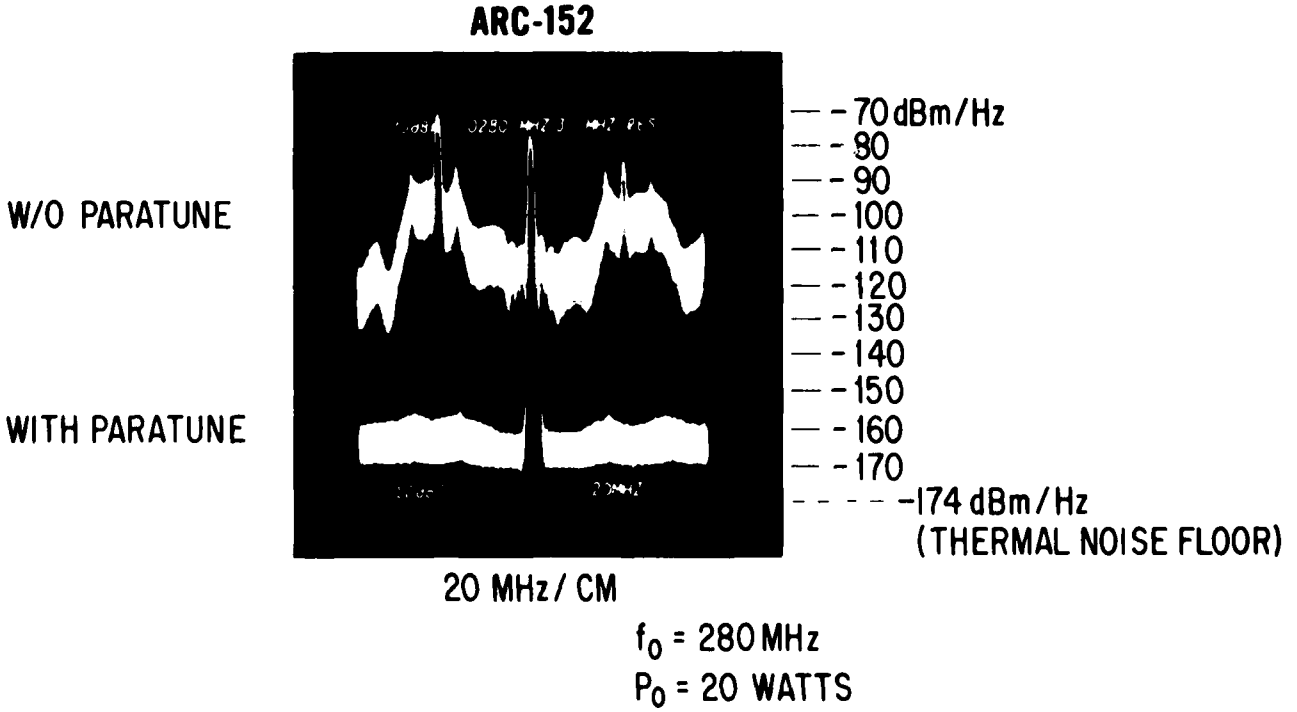
The Paratune filter will autotune to any frequency in the 25 to 40 MHz UHF band in 300 milliseconds. It can be digitally commanded to any frequency from 225-400 MHz in 300 microseconds. The Paratune Transmit Filter reduces the output broadband noise of a typical airborne UHF transceiver by 35 to 40 db, and of spurious signals by 70 to 80 db.

Current multi-radio aircraft such as the EC-135, E-4, E-3, E-2, P3-C, and C-130 have a serious interference problem caused by the broadband noise from their UHF transceivers. This is partially solved by employing receive filters or using wide frequency separations between transmit and receive channels. These solutions limit the flexibility of frequency assignment and in some cases still degrade system performance.

The Paratune Transmit Filter solves the problem of the noisy transmitter. It is currently being implemented in the AFSATCOM Terminal upgrade on the EC-135 and E-4 aircraft. It has been tested by the Navy P3-C and E-2 SPO, the Have Quick (ARC-164) SPO, the ABCCC SPO, and the E-3 SPO. All of these organizations have indicated that the tests were successful and several indicate that they plan to implement the filter in their operational aircraft.

Wayne O. Fischbach, AFWAL/AAAI, 513-255-2697

PARATUNE FILTER NOISE & SPURIOUS CLEANUP



VIBRATING BEAM ACCELEROMETER

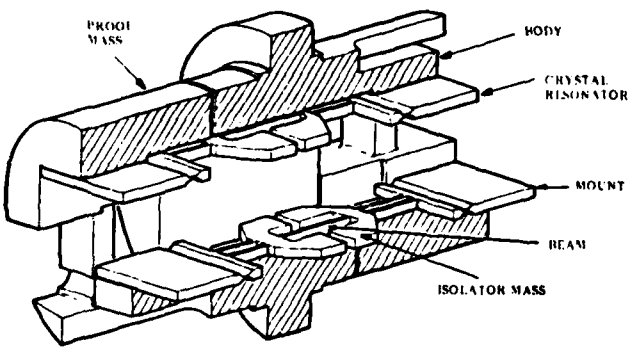
In 1980, the Avionics Laboratory started a quest to identify promising new ideas in unconventional sensors and examine their feasibility. As a result of this quest, Singer-Kearfott was awarded a one year contract to build and test a breadboard vibrating beam accelerometer (VBA). The VBA test data have demonstrated high accuracy performance and a potential for low cost production. The accelerometer makes use of the vibrational properties of quartz beams which provide a frequency shift proportional to acceleration. The device uses two quartz beams in a differential mode to eliminate acceleration senstitive error effects of a single beam. The performance which has been achieved includes the following:

Scale factor stability of 10 ug
Scale factor temperature sensitivity of 10 ppm/°F
Long-term bias repeatability of 10 ug

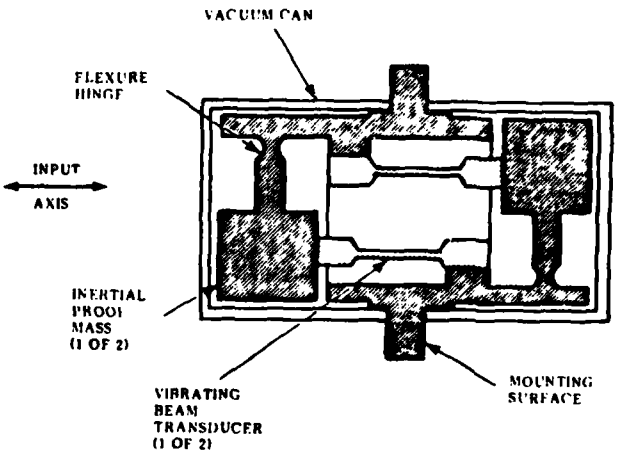
This performance compares with and exceeds inertial grade (1 nm/hr) accelerometers.

The accelerometer uses simple, low cost parts which are not critical and would be amenable to manufacturing methods analogous to the quartz watch industry. The vibrating beam accelerometer can impact the Air Force by providing inertial grade or high accuracy accelerometer at low cost, estimated at $200/axis. Present accelerometers of comparable performance cost $3000/axis. The Air Force paid $100K for this breadboard contractual effort, but additional leverage was achieved for the Air Force and DOD in that a number of organizations have expressed interest in an application for the VBA.

Richard W. Jacobs, AFWAL/AAAN-2, 513-255-5668



HIGH ACCURACY DUAL BEAM VBA CUTAWAY



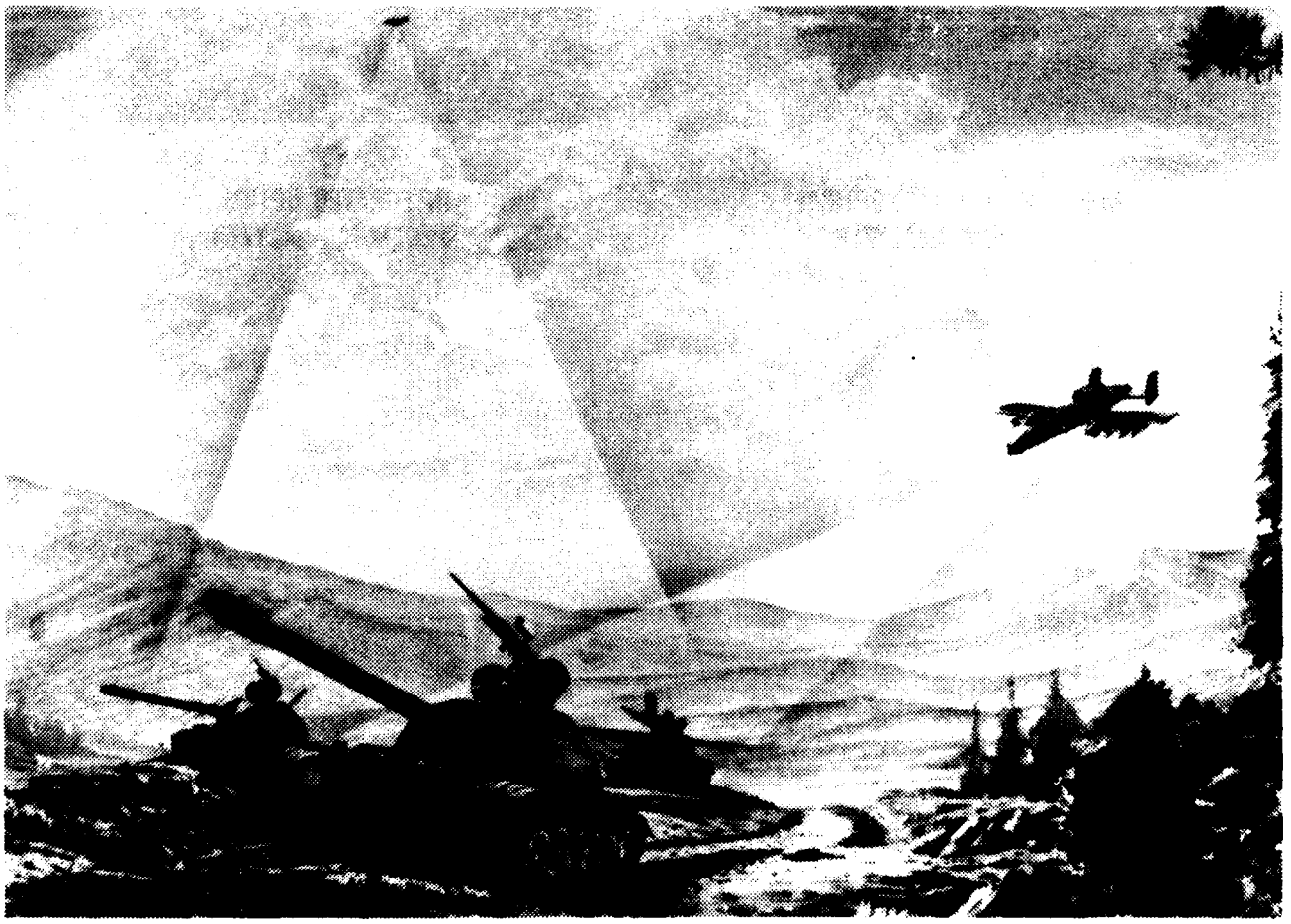
DUAL-BEAM VBA-SCHEMATIC

TACTICAL BISTATIC RADAR DEMONSTRATION

From 1978 to 1981, the Defense Advanced Research Projects Agency (DARPA) and the Avionics Laboratory sponsored the Tactical Bistatic Radar Demonstration (TBIRD) with Goodyear Aerospace Corporation, which showed that coherent bistatic radar operation is feasible. During a rigorous flight test program, TBIRD demonstrated for the first time a silent Synthetic Aperture Radar (SAR) imaging capability. By using a standoff illuminator aircraft (60 km from the target) and a receiver aircraft flying toward the target, bistatic data were obtained of tactical military targets in a desert background. Bistatic imagery was produced from these data using a contractor furnished programmable polar processor. In addition to demonstrating the feasibility of bistatic radar operation, synchronization of the illuminator and the receiver aircraft in time and phase by atomic references systems was demonstrated. The two aircraft were flown in synchronous bistatic flight paths at preselected bistatic angles. The flight paths were maintained through motion compensation using an inertial navigation system updated continuously by tracking ground reference points (beacons) and controlled by an onboard microcomputer.

The successful demonstration of bistatic radar operation showed that it is possible for an airborne surveillance or combat aircraft to operate passively near the forward edge of the battle area, hence, reducing its vulnerability to detection, location, and track.

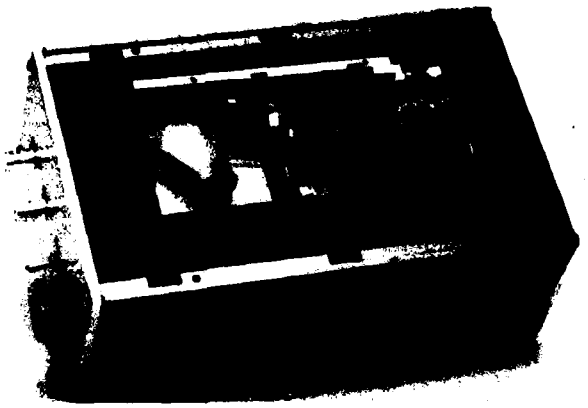
Richard J. Koesel, AFWAL/AARM-1, 513-255-5771



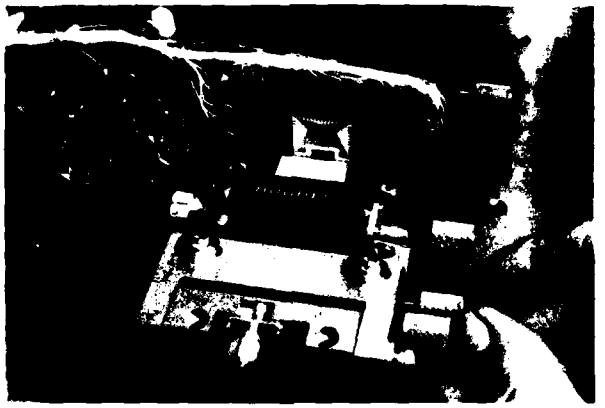
ACOUSTO-OPTICAL RF SPECTRUM ANALYZERS

In fiscal year 1981, the Air Force received delivery of two different feasibility models of Acousto-Optical (AO) RF Spectrum Analyzers, which, when fully developed, will lead to greatly improved ability to sort and identify unknown radar signals. Two AO RF Spectrum Analyzers, one in a planar integrated optics configuration and one utilizing bulk optical components to determine the extent to which miniaturization could be accomplished were delivered. Both spectrum analyzers demonstrated an ability to receive and process multiple signals, both CW and pulse, thereby demonstrating proof of feasibility of AO RF signal processing for spectrum analysis. These devices did not meet the dynamic range and resolution requirements necessary for operational use and, therefore, need additional development or advanced development work to achieve the desired performance characteristics and packaging for aircraft environments.

L/Col Gary K. Pritchard, AFWAL/AAD, 513-255-4998



MINATURE ACOUSTO-OPTICAL SPECTRUM ANALYZER



INTEGRATED OPTICS SPECTRUM ANALYZER

ALL ASPECT GUNSIGHT EVALUATION

The flight evaluation of the F-15 advanced gunsight has been completed. The potential military significance of this task is all aspect gunnery attack which should result in more firing opportunities, significantly higher probability of hit, and optimized mechanization for other than rear quarter attack. The advanced gunsights should also be implemented at lower cost and give easy pilot usage and training. This effort transitioned to PE 63203F, Project 69DF, "Integrated Gunfire Control Technology." This FY81 program accomplished the design to implement system blending and provide pilot utility in TAC simulation at Luke AFB. Simulation results demonstrated significant capability improvement over current operational lead computing sights. Subject pilots unanimously recommended flight test evaluation of the complete blended system.

Lt. James E. Rittinghouse, AFWAL/AART-1, 513-255-4794

FIREFLY III

The IFFC-I/FIREFLY III Program is a joint effort between the Flight Dynamics and Avionics Laboratories to demonstrate that integrating the flight and fire control systems will improve a fighter's survivability and accuracy, and permit more versatile maneuvers. The IFFC-I (Integrated Flight/Fire Control) contract to McDonnell Aircraft Company is for the development of the flight control system and overall integration and is managed by AFWAL/FIGX. The FIREFLY III contract to General Electric Company is for the fire control system development and is managed by AFWAL/AART. The current Lead Computing Optical Sight (LCOS) in most fighter aircraft is limited to a cone about 40° to either side of tail of the target; the FIREFLY III system expands this to 360°, or an all aspect weapon. In air-to-ground attack, current systems force the pilot to fly wings level to achieve high accuracy, leaving him vulnerable to linear predictor air defense. The FIREFLY III system allows a maneuvering attack which greatly reduces vulnerability without compromising accuracy.

Modification of the testbed F-15B aircraft was completed in December 1980 with ground testing and software testing continuing through March 1981. Airworthiness tests were flown from McDonnell's facilities in St. Louis, Missouri through April and May 1981. These successfuly demonstrated safe system operation, as well as low noise air-to-air tracking by the ATLIS II E-O sensor/tracker pod which provides line of sight data to the fire control system. Upon successful airworthiness certification, the IFFC-I/FIREFLY III system went to the Air Force Flight Test Center, Edwards Air Force Base, California, for a 15-month flight test effort. Air-to-air and air-to-ground operation of the ATLIS II pod and coupling of the flight control system have already been demonstrated successfully. The director gunnery system and maneuvering attack system, developed under Avionics Laboratory contract, have already been proven in numerous simulations and can stand alone, without coupling. The FIREFLY III system can be retrofitted to current fighter aircraft to allow maneuvering attack in air to ground. Design of the system is such that aircraft characteristics, weapon parameters, or sensors can be varied with minimal software changes.

Lt. Henry F. Ziemba, AFWAL/AART-3, 513-255-5259

INTEGRATED HEAD-UP DISPLAY

The performance and reliability of present head-up display (HUD) designs are limited by the luminous efficiency and symbol positional accuracy obtainable with conventional optical components. In addition, current HUD design practices stress the cathode ray tube (CRT) and its associated circuitry up to and beyond the limits of reliable design, thus imposing high support costs. A trade-off must also be made between CRT brightness and symbol writing capacity. The substitution of a liquid crystal matrix display for the CRT removes the brightness symbol writing constraint and provides digitally specified symbol positions, whose accuracy does not degrade as the display ages. The substitution of a diffraction optics combiner improves the luminous efficiency of the HUD optics by a factor of three and the light transmission of the combiner from 70% to 90%.

The goal of the Integrated Head-Up Display (I-HUD) program was to demonstrate the advantages associated with combining liquid crystal matrix display and diffraction optics technologies in a high brightness head-up display brassboard. In addition, it was a program requirement to demonstrate that this brassboard could be packaged in the form of the production F-16 HUD pilot's display unit.

The I-HUD brassboard system consists of two units of hardware, the pilot's display unit and the test support equipment. The design and fabrication of the pilot's display unit was the primary contractual obligation.

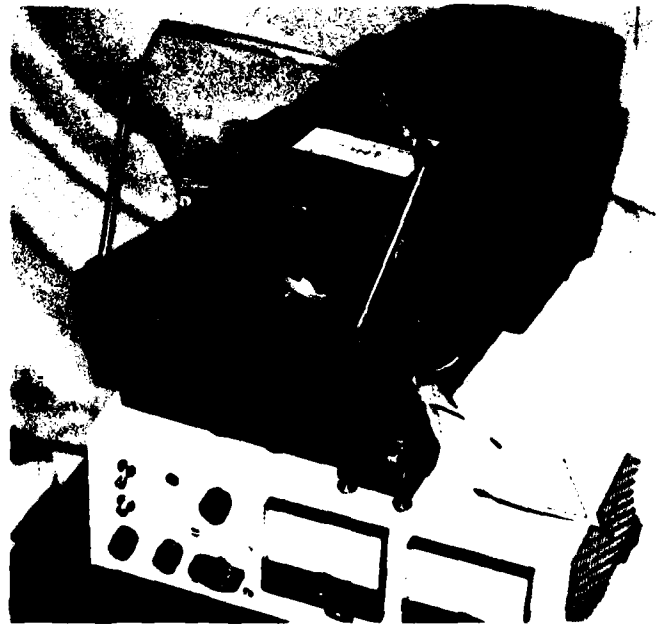
A diffraction optics combiner was used to maximize combiner see-through, symbol brightness, and instantaneous field-of-view. The combiner was designed to function as a reflector only within a narrow spectral bandwidth around 535 nanometers. As a result the combiner is transparent over the rest of the spectrum, yet is capable of reflecting 75% of the internally generated symbol luminance. This figure compares to 25% for conventional designs.

A physical LCD quad display was assembled using four 1.75 × 1.75 inch modules. Each module consisted of an electrode array of 175 × 175 pixels. The resulting 3.5 × 3.5 inch display contained an array of 350 × 350 pixel electrodes. The four modules were mounted on a common substrate and a single transparent electrode covered the entire array area.

The specular projector was designed to transfer, with minimum losses, the changes in light path direction induced by the dynamic scattering liquid crystal material into changes in light intensity onto a diffraction optics diffusing screen, The projection lamp was designed to be an intense source of nearly monochromatic green light. The luminous output of the thaliumiodide doped xenon arc lamp is concentrated near the 535 nanometers spectral peak.

The I-HUD brassboard succeeded in demonstrating the feasibility of using advanced technology in the design of head-up displays and stands as a milestone in the development of solid state display devices, and the development of high performance, cost effective head-up displays.

John F. Coonrod, AFWAL/AAAT-1, 513-255-4858

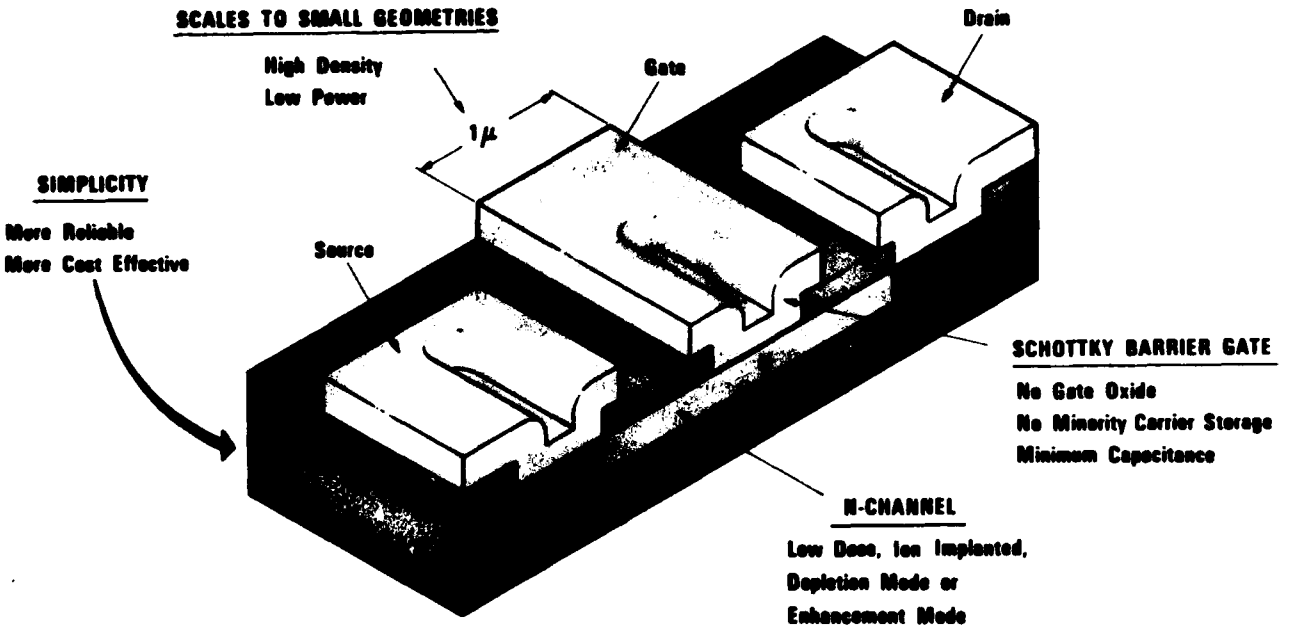


SILICON MESFET TECHNOLOGY

The metal semiconductor field effect transistor (MESFET) device, as depicted in the accompanying illustration, represents one of the more important types of solid-state devices. Its unique operation is based on the field-effect control of majority carrier current by using a metal-semiconductor Schottky junction. The well-established trend to lower operating voltages (and thereby power) along with a number of important advantages of silicon MESFETs have placed this transistor as a viable component for high density, high performance, integrated circuits for use in future Air Force signal processing applications.

The rapid technology progress and accomplishments are demonstrated by the very encouraging speed-power, temperature, and radiation test results. Various silicon MESFET devices and test circuits have been fabricated and evaluated. Threshold voltage uniformity of less than 35 mV has been achieved. Low power ring oscillators (0.1 μm gate) have been fabricated which exhibit a 2.8 nanosecond propagation delay and 1.5 fJ speed-power product. In addition, divide circuits, memory cells, and flip flops have been fabricated and evaluated. Continued development emphasizing relevant dedicated high density signal processing functions will provide the Air Force with a new viable integrated circuit technology for subsequent application in the late 1980s.

Gordon G. Rabanus, AFWAL/AADE-2, 513-255-5362



MILLIMETER WAVE CIRCUITS FOR SIGNAL, RECEPTION, AND CONTROL

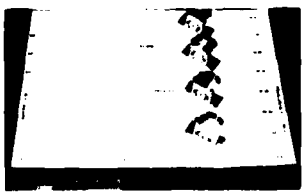
The objectives of this program were to develop high performance millimeter wave components in the 90 to 100 GHz frequency range. These consisted of wideband low loss circulators, electronic waveguide switches, electronic phase shifters, wideband low noise mixers, and low noise local oscillators. Emphasis was placed on achieving optimum noise, bandwidth, loss, and isolation performance of the devices through a proven, low cost design that can be extended for operation at any frequency in the 20 to 300 GHz range. State of the art results were achieved in all five tasks. In the wideband low loss circulator development, a unique cylindrical ferrite junction geometry was used as a basic approach to circulator construction. An analytical approach was used to calculate the optimum dimensions of the junction parts. Cylindrical shapes have the advantage of easy fabrication and assembly. The finished product is repeatable, producible, and highly reliable in its electrical and environmental performance. The four-fold improvement of operating bandwidth achieved (91.99 GHz) is also a key factor to better producibility, permitting a high degree of repeatable performance with a wide range of mechanical tolerances. The high isolation (>17 dB), excellent impedance match, and about 0.5 dB insertion loss were achieved in a junction design that supports the propagation of higher order modes. It is important that this performance was achieved through several advances in design methods, using materials which were previously considered inadequate for frequencies above 50 GHz. Improvements in analytical methods—introduced throughout the course of this program—were not only indispensable to the work performed, but constitute a significant contribution to the state of the art of ferrite component design. The most crucial contribution effects the direction of future efforts in the area of the ferrite component design and ferrite materials technology. The results of this development provide evidence that future tasks will be simpler and less expensive than was previously anticipated.

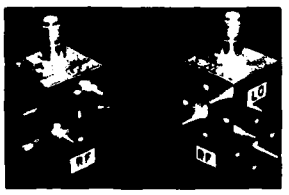
In the electronic waveguide switch development, a ferrite switch was selected over the PIN diode for its low loss and high isolation. The switch utilized a full-length ferrite junction which was magnetized by an external ferrite driver completing the dc magnet loop around the outside of the junction. Good performance (1 dB insertion loss) over a 2.7 GHz bandwidth was achieved using commercially available ferrite materials. This approach is very simple and requires fewer parts than other methods. Also, the alignment problem is not as critical. In the electronic phase shifter development, an approach using a ferrite rod weakly magnetized along its longitudinal axis was chosen as our baseline design. This approach was selected due to its overall superiority at higher millimeter wave frequencies over other methods, such as a toroidal design or a PIN diode phase shifter. The phase shifter consists of a cylindrical ferrite rod centrally supported in a waveguide. Since the rod is described by only two dimensions, diameter and length, it is easy to fabricate with a high degree of precision. The impedance matching was achieved by capactive irises and dielectric supports. The resultant phase shifter is reproducible and repeatable over a 4 GHz bandwidth with a 1 dB insertion loss.

In the low noise broadband mixer development, a crossbar waveguide mixer was designed and optimized. The basic configuration was designed theoretically and verified experimentally so that the techniques can be applied at various frequencies with proper scaling. Schottky barrier GaAs diodes were used throughout the development. The performance clearly demonstrates state of the art results in this frequency range.

A 6 dB conversion loss was achieved across the 80-100 GHz frequency range. In the local oscillator development, a resonant cap circuit was optimized to achieve 32 mW output power at 92 GHz. The resonant cap circuit was then modified to facilitate the mechanical tuning range of 22 GHz by continuous adjustment of the cap height. To further increase the output power, a two-diode combiner was also developed by placing two diodes under the same resonant cap. A combining efficiency of 90 percent was achieved. The component performance achieved under this program has significantly improved the signal, reception, and control component state of the art operation at 94 GHz. This development has direct application to advanced millimeter wave communications, radar, and ECM systems.

Robert T. Kemerly, AADM-2, 513-255-2062





DUAL MODE RECOGNIZER PROGRAM SUMMARY

Current Air Force air superiority fighters are equipped with long-range all-weather radars and medium range missiles. Operational tactics in today's air battle are limited however by the need for positive, high confidence identification of friend and foes. Current techniques available in fighters are limited to cooperative IFF response and/or identification by visual aided sensors.

To satisfy the need for an all-weather, high confidence identification, the Avionics Laboratory has successfully completed the development of the Dual Mode Recognizer (DMR), an algorithm which performs feature extraction within the signal processing of the on-board radar. Following years of algorithm development and collection of an airborne data base, the Laboratory demonstrated the ability of the algorithm to provide highly reliable target identification. The performance goals for percent of correct identification, range of identification, and false alarm rate were all met or exceeded. Transition of the algorithms to the Aeronautical Systems Division has been made.

These algorithms, when implemented as a processing mode in future radars, will provide the Air Force with a significant all-weather, day/night target identification capabiility. While the DMR algorithm may initially stand alone, providing a real capability in time for the Advanced Medium Range Air-to-Air Missile (AMRAAM) introduction, it also has good potential for integration with identification inputs from other sensors within the context of an overall IFFN fusion algorithm.

Marvin Spector, AFWAL/AART, 513-255-5144

SECTION III
FLIGHT DYNAMICS LABORATORY

F-4 STRUCTURAL LIFE EXTENSION

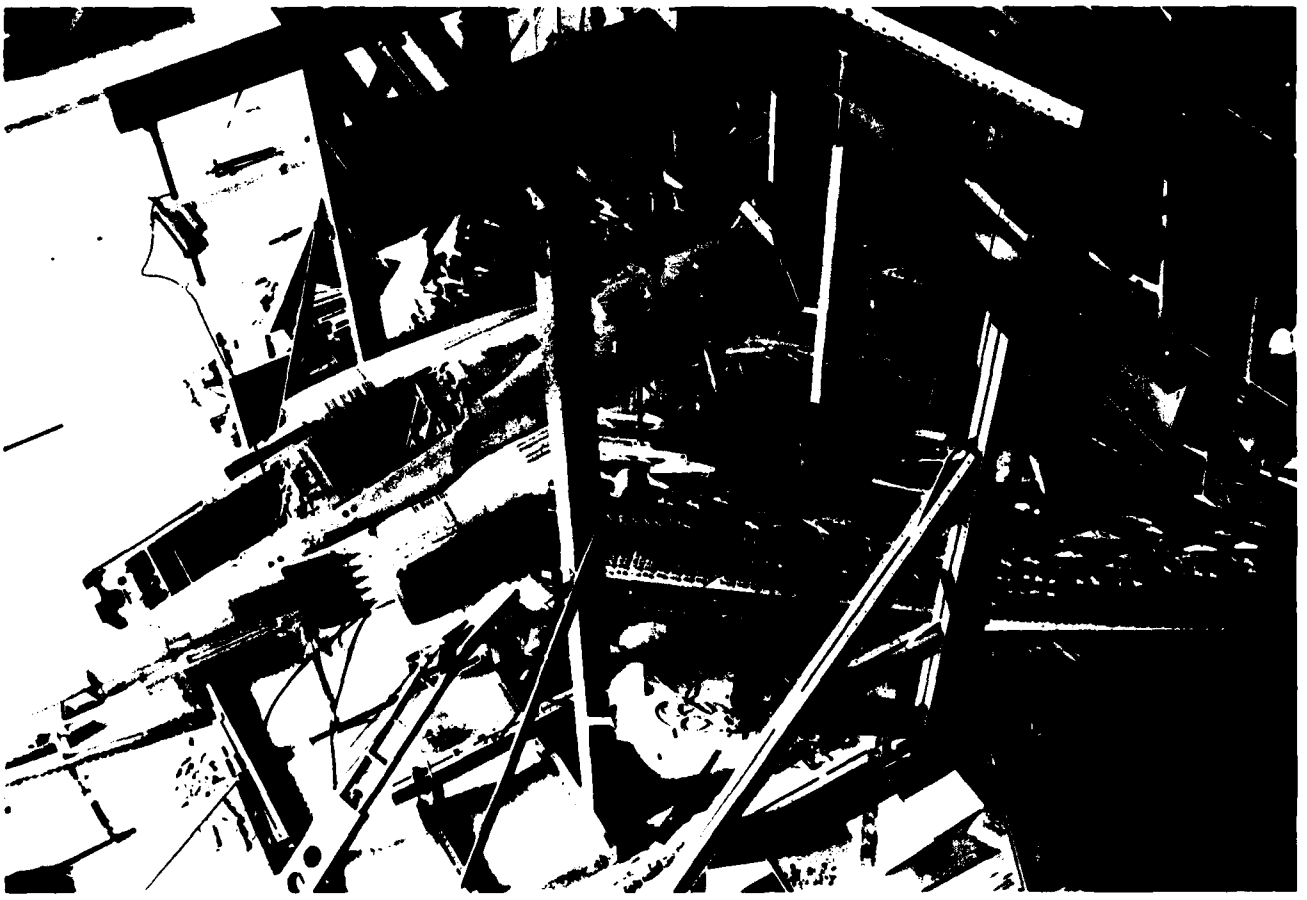
The F-4 airframe was designed two decades ago for a service life of 4,000 flight hours. Presently, the F-4C/D fleet is nearing the end of its design service life and is slated to continue in operational service. To double the structural life of the F-4C/D aircraft, the Flight Dynamics Laboratory recently completed the most comprehensive airframe fatigue test ever conducted by the Air Force.

Prior to the test setup, a damage tolerance and life assessment study was conducted. Load conditions shown to be significant to the fatigue life of the structure were simulated in the test. The distinct load distributions associated with 144 different points in the F-4 flight envelope were imposed. The test provided an automated comparison of strain measurements with prediction, as well as the capability to recall and print out data at all times in case of a catastrophic failure of the structure. Four independent levels of automatic protection were functional during the entire progress of the test program, making it the most failsafe system yet devised in the testing industry.

At prescheduled intervals during the fatigue test program, structural modifications were made to the test aircraft which were the same as those modifications made to F-4 service aircraft at the same number of flight hours. Included were modifications to the pylon hole, wing fold rib, main spar fasteners, and fuel cell. A major achievement of the test program was the physical proof that the modified structure indeed provided the required airframe structural life extension.

About 4,000 F-4 aircraft are currently in operational service by the USAF and allied nations. The fatigue test program proved the adequacy of the structural modifications made to the F-4 airframe, determined additional modifications required, and provided information on the appropriate scheduling of these modifications for the entire F-4 fleet. An estimated $1.5M was saved by conducting the fatigue test program in-house.

Robert L. Schneider, AFWAL/FIBT, 513-255-5059
Sanford Lustig, AFWAL/FIBT, 513-255-5059



COMPOSITE DEPLOYMENT MODULE

ıring the MX missile development program, the inum baseline deployment module (DM) for the did not meet system structural requirements. eep the program on track, the Flight Dynamics ɔratory developed a full-scale composite DM d on the MX configuration and requirements. ing graphite/epoxy, a detail design was developed he interior structure of the deployment module, re- ng the baseline aluminum outer shell. The design ll static and dynamic loading conditions, as well as rical and nuclear environments. A full-scale com- nt was fabricated including all reentry vehicle mounting fixtures. A dynamic test was conducted he unit with a full complement of realistic RV lators to determine critical data on deflection and ral frequency. In all test conditions, the composite exceeded MX requirements and was within 10-15% edicted values.

The composite deployment module had an actual weight savings of over 40 pounds and an estimated cost savings up to 10% per unit compared to the aluminum design. This significant weight reduction offers potential missile benefits in terms of increased fuel capacity or payload, resulting in additional range or target footprint for the MX. A substantial reduction in assembly cost was achieved with the composite DM through a reduction in part count by two orders of magnitude.

Recently, the composite deployment module was selected as the new baseline for the MX missile system. The composite DM was instrumental in preventing the need to slip the MX development schedule to redesign the original aluminum baseline deployment module.

Capt Barry A. Eller, AFWAL/FIBA, 513-255-5006

SUPERPLASTIC FORMED ALUMINUM STRUCTURE

The increasing technical complexity and performance of military aircraft reveal a need to reduce the cost and weight of aircraft structure. The Flight Dynamics Laboratory has demonstrated that superplastic forming (SPF) of high strength aluminum alloys is a significant breakthrough in producing unique structural configurations not possible with current aluminum forming processes.

SPF aluminum is a technology that allows the forming of one piece wing and fuselage structural elements with integral flanges and stiffeners from thick gage, high strength, aluminum sheet stock. SPF aluminum parts replace built-up components that employ labor intensive, mechanically fastened subassemblies or extensive machining operations.

The only full-scale SPF aluminum airframe component ever produced, a T-39 forward fuselage frame, was fabricated and evaluated under this Laboratory program. The SPF design had 5 detail parts and 20 fasteners, compared to 18 detail parts and 187 fasteners for the baseline component. The SPF part resulted in a 35% cost savings and a 22% weight savings.

SPF aluminum can provide significant payoffs to current and future Air Force systems. A recent Laboratory study has shown that 22% of all structural aluminum in a 500,000 lb transport, such as CX, could be replaced by SPF aluminum components. This would result in savings as high as $600 million in life cycle costs and 100 million gallons of fuel for a 100 aircraft fleet.

James Tuss, AFWAL/FIBC, 513-255-2582

INTEGRAL FUEL TANK TEST METHODS AND CRITERIA

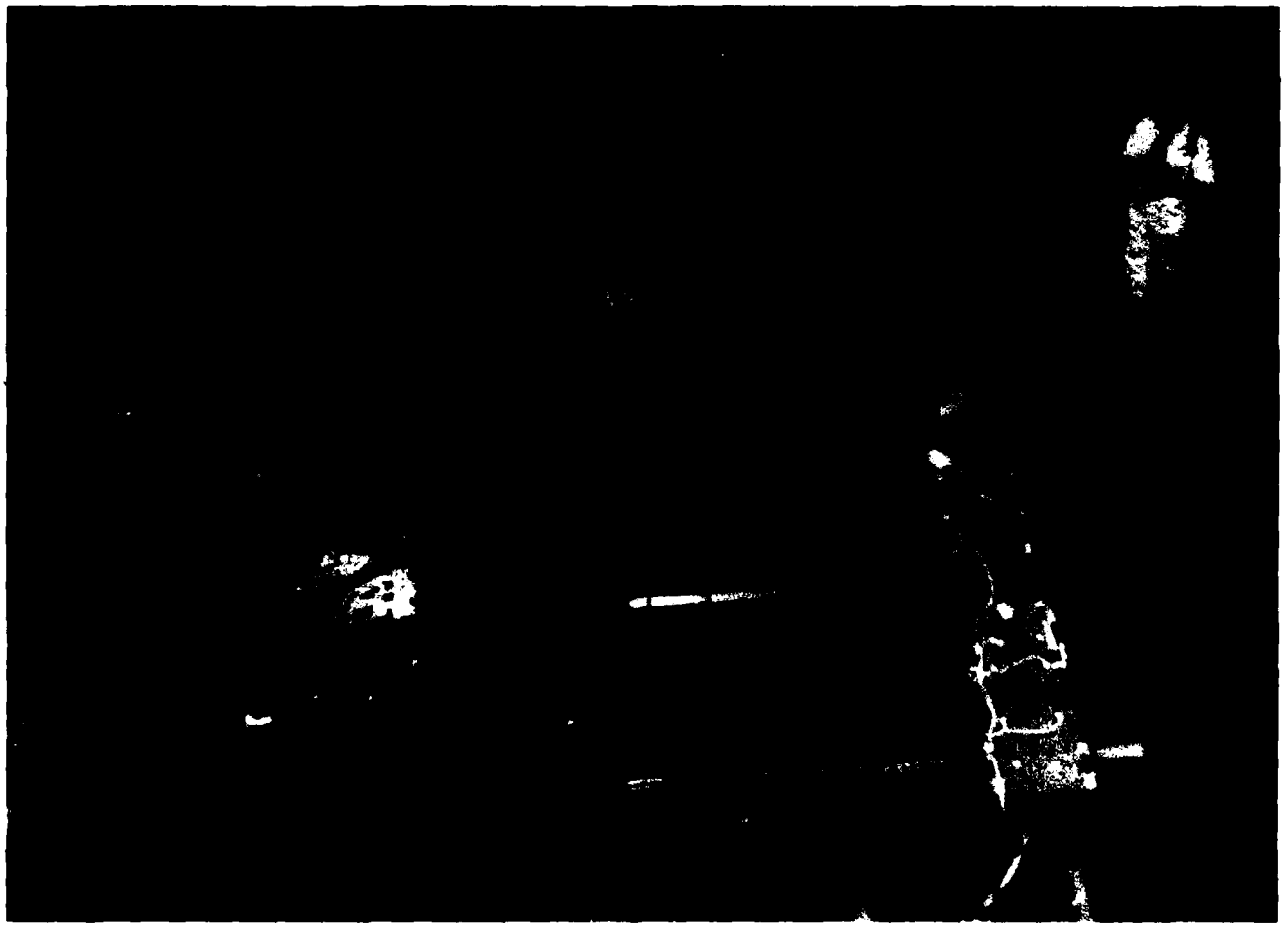
Although the repair of fuel leaks in aircraft fuel tanks has been one of the highest maintenance cost items during the service life of DOD aircraft, fuel containment has been a secondary consideration to structural integrity, durability, and survivability.

Previous testing for fuel containment has proven to be inadequate because it could not uncover design deficiencies that result in fuel leakage. It was determined that fuel containment can be affected by basic structural design and fabrication, sealing materials and methods, and the environmental conditions to which aircraft are exposed.

Therefore, to test integral fuel tanks, an in-house facility was designed and constructed by the Flight Dynamics Laboratory. This in-house facility, a first in this country, has the capability of testing two integral fuel tanks independently. It utilizes computer-controlled fatigue and static loading under various environmental conditions of temperature (– 65 ° to 275 °F) and internal pressure, with and without JP-4 fuel. A complete data acquisition system is also available.

The facility is currently being used for comparison tests of various sealing concepts of integral fuel tanks. To date, eight sealant concepts have been tested utilizing F-16 type integral fuel tanks. The results of this testing are being used to develop design criteria and methodology to improve the in-service life of future integral fuel tanks.

Martin D. Richardson, AFWAL/FIBT, 513-255-2291



A-7D COMPOSITE OUTER WING PANEL TEST PROGRAM

The A-7D Composite Outer Wing Panel Test Program was a follow-on effort to a Materials Laboratory program concerning advanced composite primary wing structures. The first phase consisted of selection of materials and development of the manufacturing processes, tooling, and production controls. Phase II included laboratory static and fatigue tests by the contractor, LTV, and installation and service tracking of eight composite outer wings on Air National Guard A-7 aircraft.

During Phase II, this graphite and boron-epoxy structure was certified for 750 hours of flight. As the composite outer wings reached 750 hours of flight, it was proposed to remove them from the aircraft. Since these composite outer wings were the only composite primary structures on Air Force aircraft, a study was made to determine what additional efforts might be accomplished to gain futher benefits from the program. It was decided that a joint Flight Dynamics Laboratory/Materials Laboratory program would be initiated to certify the composite outer wings for the entire life (8000 hours) of the A-7 aircraft. This program would provide additional flying experience and confidence in the potential for the use of composites as primary structures. The Flight Dynamics Laboratory was to continue the fatigue test program in-house utilizing its Structures Test Facility. The Materials Laboratory would continue its service tracking and field inspection program. One of the flying articles was removed for use as the fatigue test specimen. The fatigue test was started in July 1980 and completed in March 1981.

The A-7 composite outer wing panel successfully substained 16,000 simulated flight hours with no structural failures. Therefore, the composite primary structure is adequate for a lifetime of 8,000 flight hours.

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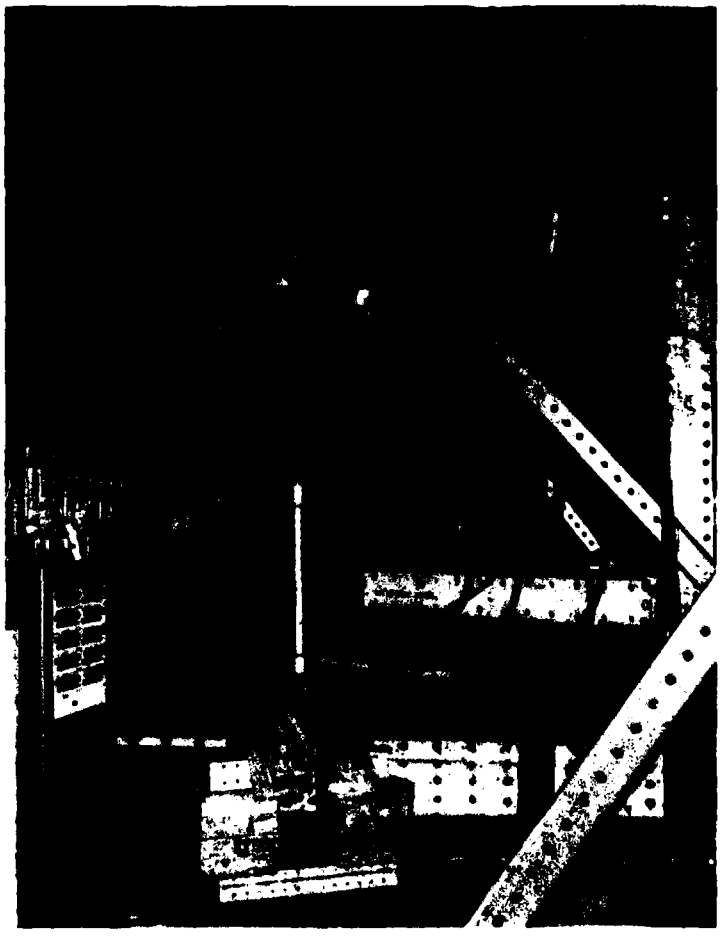
Frank L. Fechek, Jr., AFWAL/MLSS, 513-255-3370



F-16A LAMINATED CANOPY

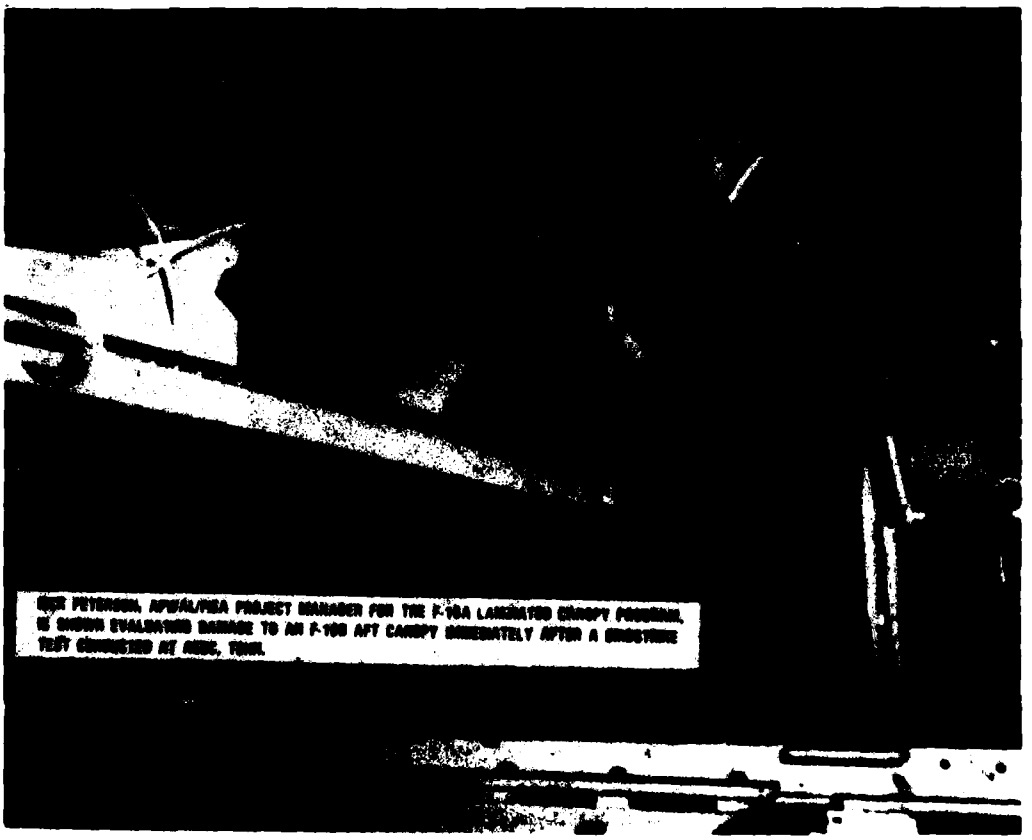
Flight safety hazards that have recently received increased awareness include the aircraft birdstrike problem and the potentially serious coating loss problems due to erosion and pitting. To combat these problems, the Flight Dynamics Laboratory has developed and safety of flight qualified a new crew station cockpit transparency for the F-16 aircraft.

The new laminated plastic transparency system provides 350 knot, four pound birdstrike protection and multi-year service life. Two versions of this design were selected by the F-16 System Program Office for use on production F-16 aircraft, and will be provided as government furnished equipment to the F-16 contractor.

The Laboratory's alternate canopy program for the F-16 resulted in three qualified sources for fabrication of F-16 laminated canopies. By using multiple sources, the Air Force enhanced competition and provided for alternate production options, while saving $8 million in acquisition costs for the balance of the F-16 aircraft production program. Since the laminated canopy configurations are expected to be in service twice as long as the current production canopy, fewer canopy changeouts and less overall maintenance should be required throughout the F-16 fleet. As a result, an additional life cycle cost savings of $175 million is projected for the total 1,388 USAF F-16 aircraft buy.

The improved characteristics of the new laminated canopy design has enabled the USAF to negotiate, for the first time, a minimum four year service warranty period. Under the warranty, defective canopies will be replaced at no increase in cost to the government.

Richard L. Peterson, AFWAL/FIEA, 513-255-6524



COMBINED ENVIRONMENTS RELIABILITY TESTING

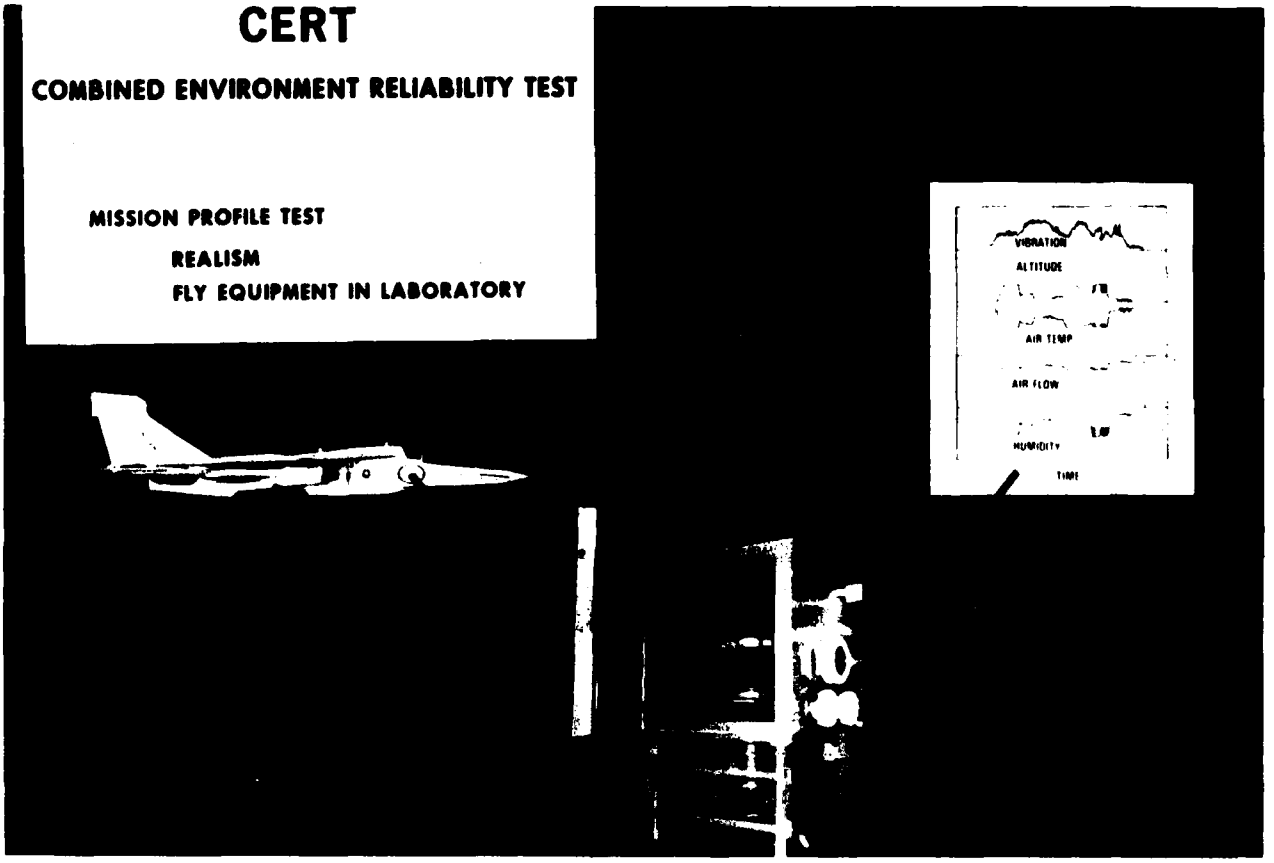
Once deployed, the performance and reliability of avionics systems are generally much lower than specified by the procuring activities and desired by the using commands. This frequently occurs because the avionics systems are subjected to unrealistic environmental test conditions prior to deployment in the field.

The Flight Dynamics Laboratory recently completed a technology program that promises to have a far reaching impact on the acquisition of aeronautical equipment for future weapon systems. The program involved the development, implementation, and verification of a significant new test methodology called Combined Environments Reliability Testing (CERT). CERT essentially combines several critical parameters (temperature, vibration, altitude, and humidity) into a single test. Each parameter profile is determined analytically or selected on the basis of previous flight test data. In this way, the CERT facility actually "flies" the equipment being tested through a selected mission profile using all test parameters simultaneously.

Test results from the two-year validation phase of the CERT program showed a much improved correlation with actual field failure data over that achievable with other currently used methods. The CERT test methodology can be used to accurately predict, in a laboratory environment, the failure rates and modes that equipment would experience when actually operating in the field. Thus, the CERT concept can be used to determine the accuracy of a contractor's equipment life design predictions under realistic environmental test conditions.

As part of the CERT development and evaluation program, the Laboratory completely revised the standard DOD dynamic testing methods to be more realistic, tailorable, and cost effective. These revised testing methods, when combined with the CERT technology, should contribute significantly to the deployment of more cost effective and reliable equipment systems.

Dr. Alan H. Burkhard, AFWAL/FIEE, 513-255-6078



SPACE SHUTTLE LANDING GEAR HARDWARE TESTS

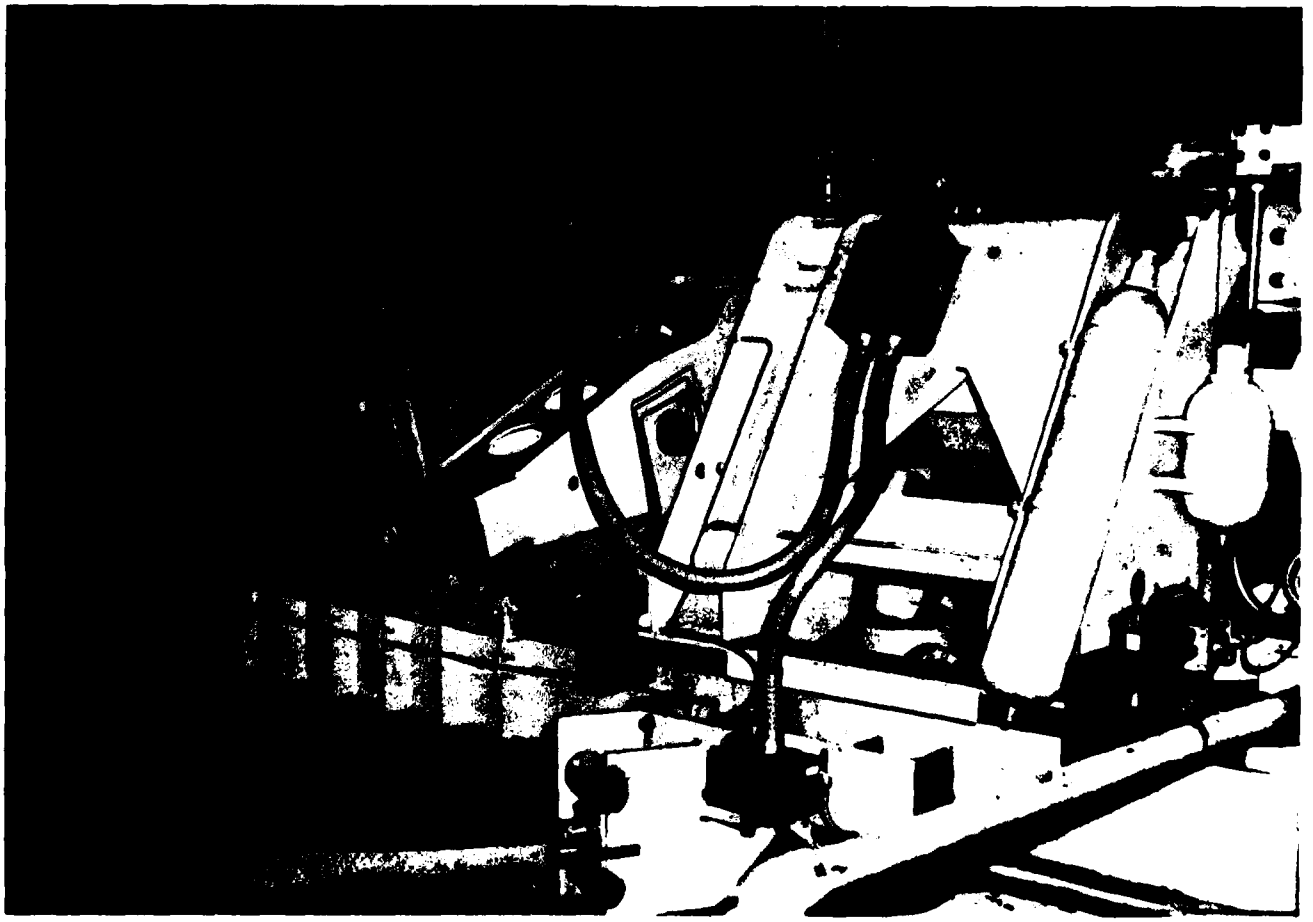
Prior to the first flight of the Space Shuttle Columbia, the Flight Dynamics Laboratory was called upon to conduct development and certification testing of Columbia's main landing gear tire/wheel/bearing assembly. Based on the results of those tests, the landing gear hardware was certified as "go" for the first flight of the shuttle.

Subsequent to the first flight certification, the Laboratory continued testing to develop landing gear hardware development for heavier versions of the shuttle projected for future missions. Although the gross weight for the second flight of the shuttle is expected to be only slightly higher than that of the first, the landing gear hardware still requires experimental validation at the higher weight condition.

Anticipating delays in delivery and certification of the second flight tire/wheel bearing assembly, NASA's Johnson Space Center requested the Flight Dynamics Laboratory to conduct additional tests on the main landing gear hardware used on Columbia's first flight. Results of that testing verified that the wheel and bearing assembly designed and certified for the first flight can withstand the increased loads associated with the more severe dynamic environment expected for the second flight, using an upgraded tire designed for a heavier gross weight vehicle.

The Flight Dynamics Laboratory testing in support of the shuttle program was conducted on the Landing Gear Development Facility's computer controlled dynamometer system. Testing on this dynamometer has been a key element in the design, development, and certification of landing gear hardware for the shuttle. As the gross weight of the shuttle continues to grow, imposing increasingly more severe dynamic conditions on the tires and wheels, this machine will continue to provide the only known capability in the DOD to certify the shuttle's landing gear hardware.

Igors Skriblis, AFWAL/FIEM, 513-255-6891



AIRCRAFT GROUND MOBILITY SYSTEM

For many years, the vulnerability of airfield pavements during enemy hostilities has been a matter of continuing concern. As part of the solution to this problem, the Flight Dynamics Laboratory developed an Aircraft Ground Mobility System (AGMS) for the F-16 to provide the capability of moving aircraft over bomb damaged pavement or unstabilized, off-runway soil surfaces.

The AGMS consists of wide, Hytrel polyester elastomer track segments which are assembled together and strapped around the aircraft tire. The AGMS redistributes the aircraft tire load over a larger ground contact area, reducing the over-ground bearing pressures by over 70 percent. Specifically, for the F-16 application, nominal unit ground pressures were reduced from 275 psi down to approximately 65 psi.

The AGMS was tested in-house in the Laboratory's Landing Gear Development Facility and on a GF-16 aircraft on taxiway and sod surfaces at Wright-Patterson Air Force Base. The loads experienced during these tests were significantly below the F-16 landing gear design limit loads. Both the nose and main landing gear mobility systems performed satisfactorily. Rut depths during tow testing over sod were approximately 1 to 1 ½ inches. The tow loads rarely exceeded 4,000 lbs, well below the design limit load of 9,257 lbs.

The AGMS is a temporary installment with a quick attachment/detachment scheme. It will provide the ability to move aircraft to survivable takeoff sites following an attack on the airfield, greatly enhancing the post attack effectiveness of aircraft such as the F-16 or F-15. It will also allow the airfield commander the option of concentrating the rapid runway repair on the runways, instead of trying to repair both runways and taxiways. The AGMS provides an additional advantage of protecting aircraft tires from debris on battle damaged surfaces.

David J. Perez, AFWAL/FIEM, 513-257-2129

DIGITAC OPTICAL FLIGHT CONTROLS

Future tactical aircraft will need reliable and combat survivable systems to continue the aircraft's effectiveness against the ever expanding threat. To meet this challenge, the Flight Dynamics Laboratory has developed a dual redundant fiber optic multiplexed (MUX) data bus and successfully demonstrated it on a modified YA-7D test aircraft.

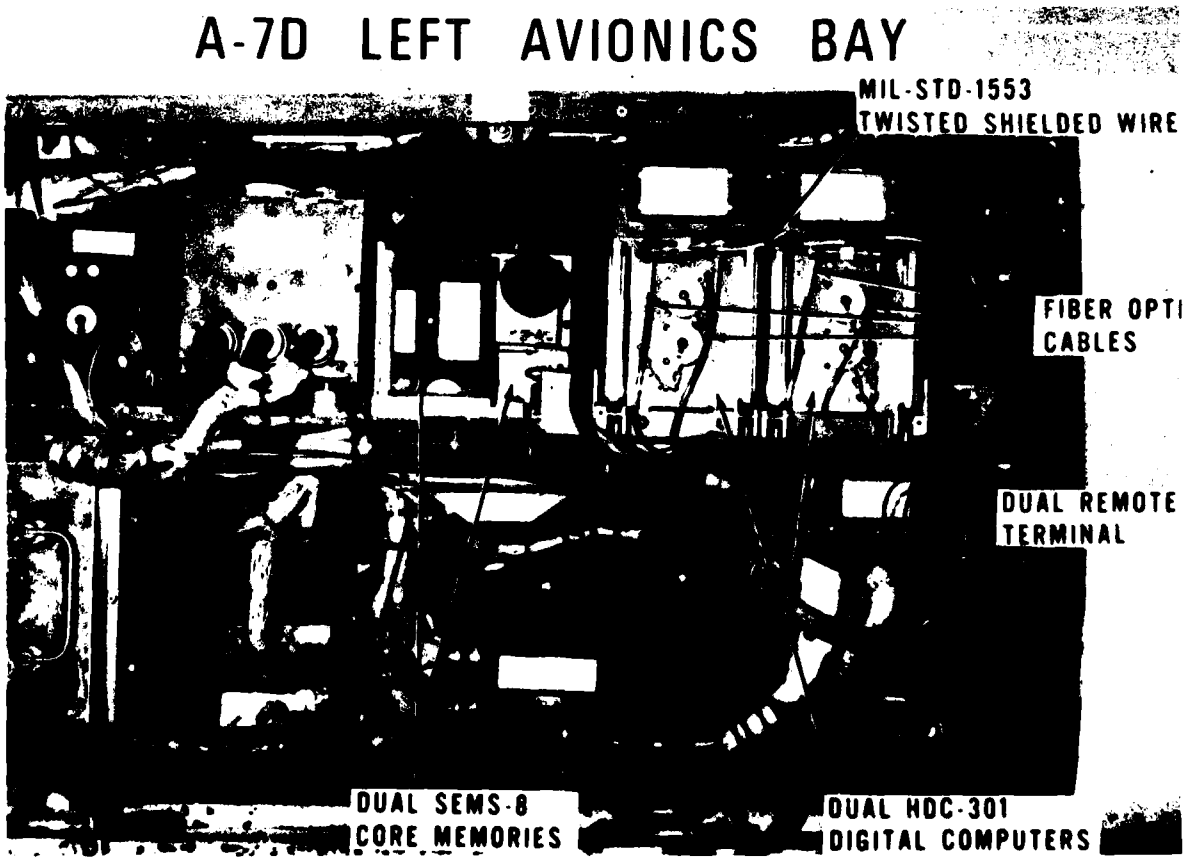
Transmitting flight safety critical data optically, the dual fiber optic MUX busses operate simultaneously under software control programmed in DIGITAC's digital flight control computers. These computer units control the data being transferred over the fiber optic MUX busses to and from remote terminals which interface directly with the aircraft's flight control system elements. Together, these units provide the stability and control augmentation and automatic pilot functions necessary for precise aircraft path control.

Upon command from the computers, the remote terminals convert analog inputs from flight parameter sensors to optical data pulses. The computer calls these data as required and calculates the control surface position commands which it sends to the surface actuators over the optical data bus. The redundant fiber optic MUX bus design emphasizes detection of functional failures and ensures failsafe operational capability by electrically isolating failures.

Fiber optic MUX busses are not bandwidth limited as are electrical wire systems. These small, lightweight pairs of fiber optic cables can replace large bundles of wires and be easily distributed within the aircraft for increased survivability. Simulated lightning strike tests conducted on the DIGITAC system have demonstrated that fiber optic MUX busses provide excellent electrical hazard protection.

DIGITAC's dual redundant fiber optic MUX busses have operated flawlessly in over 52 test flights in the YA-7D. This is the first time a "fly-by-light" technique has been used to transmit flight critical data for all three-axes stability and control augmentation functions in an aircraft. Combining fiber optic multiplex data techniques with digital flight controls has significant potential for improving mission effectiveness, flight, safety, system reliability, and combat survivability.

Forrest R. Stidham, AFWAL/FIGL, 513-255-4607



DIRECT DRIVE VALVE

The Flight Dynamics Laboratory has successfully flight demonstrated a direct drive valve for fly-by-wire (FBW) system flight control actuators. The direct drive valve simplifies flight control actuation, increases reliability, decreases cost, and improves operational readiness.

Under the Laboratory program, direct drive valves and their associated electronics were designed, adapted to an F-4 aileron actuator, and demonstrated in flight test. The valves provide aircraft control by transforming electronic control signals in FBW flight control systems to control surface actuator position.

Direct drive valves greatly simplify flight control actuation. With FBW flight control, the control signal must be converted from a low power level electrical signal to a mechanical input through a secondary actuator which has several complex hydraulic amplification stages. This secondary actuator contains numerous precision machined parts, is sensitive to hydraulic fluid contamination, and requires specialized support equipment and skills to maintain. Direct drive valves eliminate the need for secondary actuators by using new samarium-cobalt magnets which control hydraulic fluid flow for a control actuator using a one step valve. Less expensive and rugged electronic devices eliminate the precision machined parts and contamination sensitive elements.

The F-4 flight test demonstrates the mechanical simplicity of the direct drive valve. The number of manufacturing processes required to produce the valve was cut from 334 to 70. The direct drive valve also improves operational readiness by increasing mean-time-between-failures from 683 to 2,185 hours and decreasing maintenance manhours per flight hour from 18 to 5.

Gregory J. Cecere, AFWAL/FIGL, 513-255-4607

INTEGRATED FLIGHT FIRE CONTROL/FIREFLY III FIRST FLIGHT

For air-to-surface gunnery and bombing missions, maneuverability is routinely sacrificed to achieve the desired accuracy. Conventional attack profiles frequently result in considerable vulnerability of the attacker to relatively unsophisticated target defenses. Soon however, AFWAL developed technology will enable fighter pilots to fire or drop weapons accurately while flying attack profiles that were previously impossible.

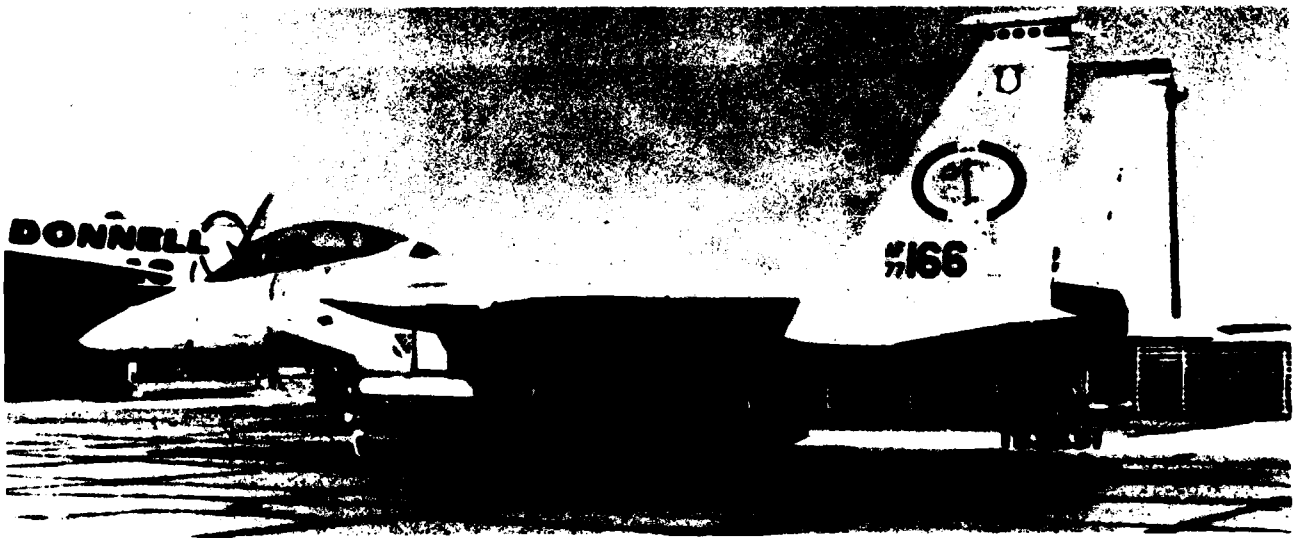
The AFWAL program, Integrated Flight Fire Control (IFFC)/Firefly III, is a joint Flight Dynamics Laboratory/Avionics Laboratory effort to develop, integrate, and test F-15 flight and fire control systems with an optical sensor/tracker pod.

Externally, the IFFC F-15 testbed looks like a production F-15. The only external modification to the test aircraft is the optical sensor/tracker pod mounted on the left forward missile-well position. Extensive F-15 internal modifications include adding a digital computer coupler interface unit to link flight and fire control algorithms, modifying the F-15 control augmentation system computers, and modifying the central F-15 computer.

Although the IFFC/Firefly III program is only in the early stages of development testing, first flights were successful and highly significant in demonstrating that the basic components of the IFFC technology indeed "play together" satisfactorily.

IFFC technology provides tremendous advantages for pilots. In the air-to-air mode, IFFC is especially impressive in its performance at high offset angles and high closure rates where the probability of hitting targets was traditionally near zero. In the air-to-ground mode, the pilot will have greater standoff distances and can release his munitions while maneuvering. The end result translates into improved combat effectiveness and survivability.

James A. Kocher, AFWAL/FIGX, 513-255-4819



PICTORIAL DISPLAY FORMAT DEVELOPMENT

Advances in command and control systems, on board computers, increased aircraft performance, and airborne guided weapons have multiplied the information that can be presented to the pilot, and have outstripped the capability of traditional dedicated instruments to present this information efficiently. This trend leads to pilot information overload and increased workload, with possible decreases in mission effectiveness.

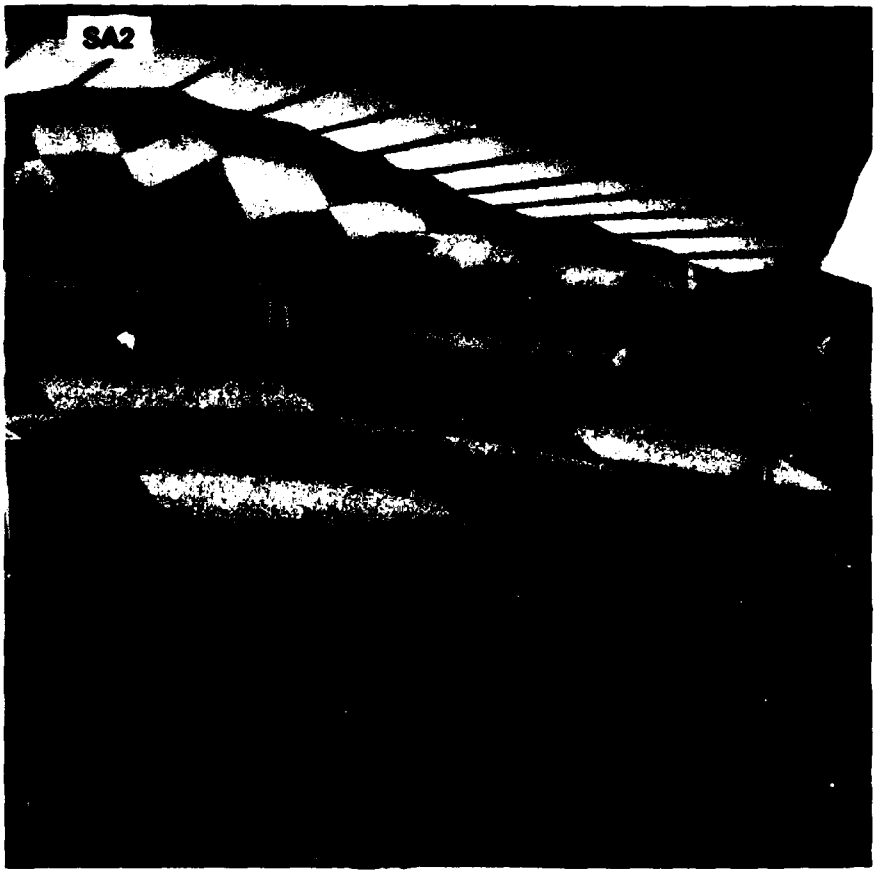
In searching for a solution to this problem, the Flight Dynamics Laboratory is conducting a program that could give future pilots advanced pictorial displays for mission status and subsystem checklists.

The program objective is to design an efficient information interface between the pilot and the aircraft. The approach is to replace traditional alphanumeric (electromechanical) devices with computer drive, TV-like electro-optical displays. The major advantage offered by full-color, electro-optical displays is the ability to present pictorial formats and color coded information. The study emphasizes data coding for efficiently presenting information in a simplified form that is quick and easy to understand and interpret.

Under the Laboratory program, pictorial display formats were developed for several classes of information portrayal. These included flight, navigation, tactical situations, subsystem status, stores management, engines, and emergencies. Mathematical algorithms were generated to drive the drawings and define the software requirements for the displays. The software development also considers design factors such as refresh rate and update rate on the cathode ray tube (CRT), computer memory requirements, writing speed, and number of vectors per picture.

Displaying information pictorially has the potential for greatly simplifying cockpits now crowded with gauges, dials, and CRTs with alphanumerics. The result can be a significant reduction in pilot workload, particularly when performing tasks under stress.

Dr. John M. Reising, AFWAL/FIGR, 513-255-6895



Threat Envelope with Graphic and Terrain Data:

CONTINUOUSLY RECONFIGURING MULTI-MICROPROCESSOR FLIGHT CONTROL SYSTEM

A new multi-microprocessor architecture has been proposed to reduce overall hardware, software, and life cycle costs of flight control systems while maintaining high reliability and fault tolerance. The promising microprocessor design concept was conceived by the Flight Dynamics Laboratory.

The Continuously Reconfiguring Multi-Microprocessor Flight Control System (CRM²FCS) is a scheme for dynamically redistributing, in a multiprocessor system, the tasks to be performed among all functioning processors in a continuing process of reconfiguration. This approach allows continuous spare checkout, latent fault protection, and elimination of failure transients due to reconfiguration delay. By treating reconfiguration as the norm rather than the exception, failures can be handled routinely rather than as emergencies, resulting in predictable failure mode behavior.

A major benefit from CRM²FCS is flexibility for expansion. Experience has shown that innumerable changes in system design occur throughout the production cycle of an aircraft. These changes are very expensive because a single change propagates other changes throughout the hardware and software of the system. The CRM²FCS modular hardware and software provide the potential to greatly reduce these costs. Software changes are easy to program, maintain, and update.

Capt. Scott L. Maher, AFWAL/FIGL, 513-255-7229

RCS SIGNATURE REDUCTION

In the past, penetrating tactical fighter aircraft depended primarily on speed and agility for survival in combat situations. Today, these two performance parameters, while still important, are insufficient by themselves to assure mission success against the sophisticated radar-directed air defense systems now deployed.

To counter this development, the Flight Dynamics Laboratory has undertaken a technology program to investigate effective means of reducing aircraft radar cross section (RCS). The principal techniques being investigated include configuration shaping and radar absorbing structure.

Initial results from this program have been highly satisfactory. Large-scale experimental data have shown that it is possible to significantly reduce the RCS of advanced tactical aircraft with only minor impact on mission performance.

Additional RCS reduction technology efforts are planned to build upon the established data base, and blend it into an effective set of RCS design guidelines for use in future aircraft development programs. This will result in tactical aircraft designs having enhanced penetration survivability and more weapons on target.

Russell F. Osborn, AFWAL/FIMM, 513-255-3788

AERO CONFIGURED MISSILES

ıditional missiles have been shaped to accom-
te the requirements of carriage, propulsion
ns, guidance and control systems, or warheads.
.erodynamics, which result from the external con-
ıtion, have been given a secondary role. New mis-
;oals emphasize extreme range and maneuverabili-
'hese goals can only be reached if the aero-
nic characteristics are optimized. The Flight
mics Laboratory has completed an effort which
s the way toward aerodynamic optimization for
es.

ɛ objective of the program was to exploit
lynamic potential in missile design in the same
er as is currently done in aircraft design. A general
mission segments, such as boost, climb, and cruise
examined to evaluate the sensitivity of the
lynamics in improving performance along the seg-
. The aerodynamic parameters which showed the
ɛst payoff were translated into optimized missile
ɛs. Wind tunnel tests were performed to verify the
ɛd results and to provide a data base for future
ns.

The program initially produced shapes which were unconstrained by any factor other than aerodynamics. A second phase in the program took account of the constraints of propulsion, guidance and control, and mission range. Wind tunnel tests revealed that only small performance losses resulted. A preliminary design concept was explored in the third phase, with application to goals of baseline advanced missiles to reveal the extent of improvements. Among these improvements, the mission range was doubled over the baseline missile by the enhanced aerodynamic configured missile.

The results of the program have been published and widely distributed to industry. The family of shapes have been used in new technology programs to study boost-glide missile concepts and to reduce the observables of air launched missiles. A new appreciation of the advantages of improved aerodynamic characteristics has been generated in the missile design community.

Val Dahlem, AFWAL/FIMG, 513-255-7222

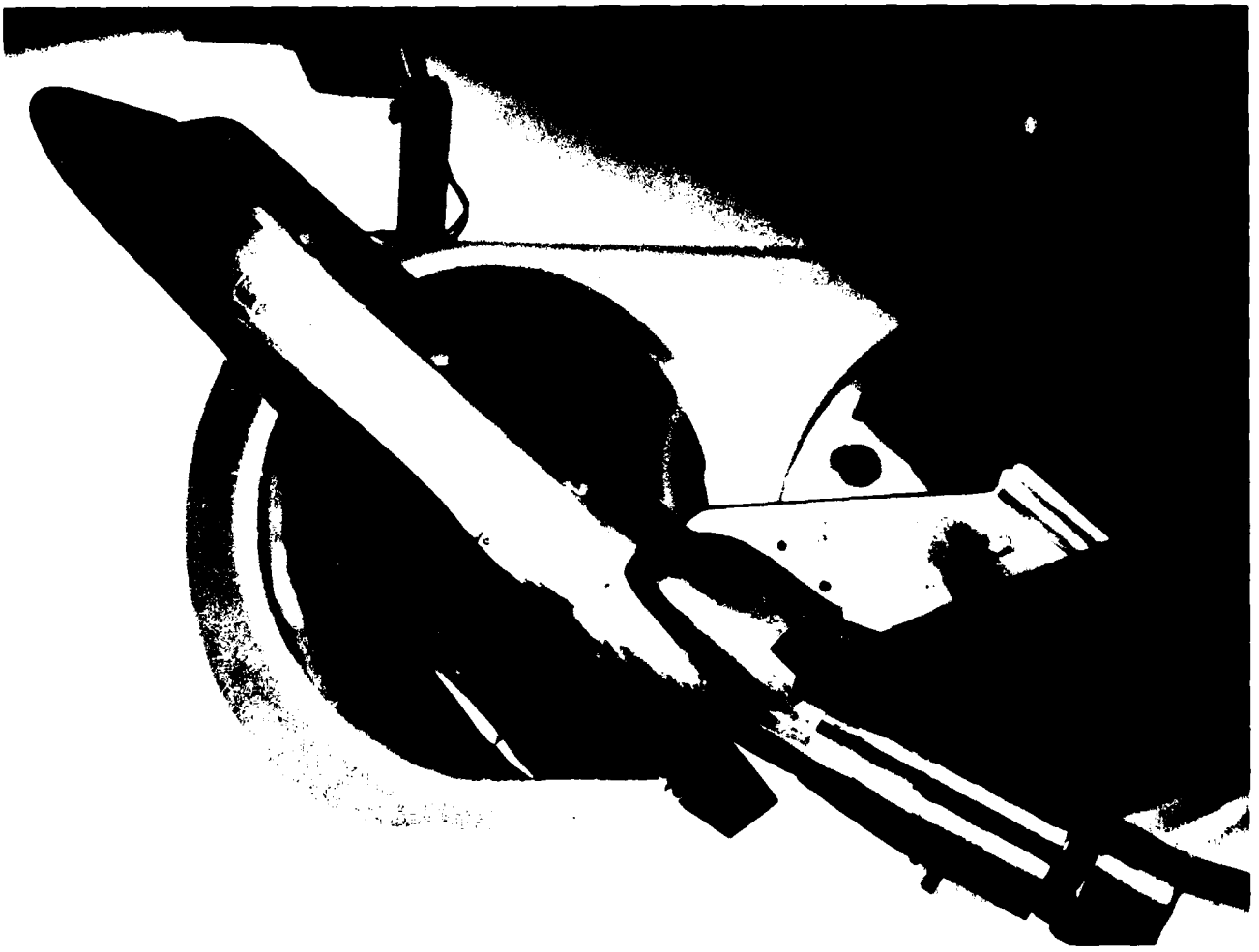
SPACE SHUTTLE AEROTHERMO HEATING

The Flight Dynamics Laboratory is participating in the DOD Space Transportation System Test and Evaluation program under the lead of the Air Force Space Division. In this role, the Laboratory was assigned the task of conducting an independent review of the wind tunnel aerothermodynamic data to determine the shuttle's adequacy to support Air Force missions. The Laboratory review indicated serious deficiencies in the data base on the oribital maneuvering system (OMS) pods at lower vehicle angles of attack. This study resulted in a documented need for additional wind tunnel experimentation prior to flight test operations.

Faced with this need and a lack of support by NASA, the Flight Dynamics Laboratory elected to fund these critical experiments and conduct the effort in-house. Two decisive experiments were conducted with Space Shuttle models modified and instrumented by the Laboratory. These experiments were run at Mach 8 at AEDC and at Mach 14 at the Navy Tunnel 9. Data were gathered, correlated, and extrapolated to flight conditions which demonstrated conclusively that the Shuttle would not survive the rigors of high cross range missions without additional thermal protection in the critical OMS pod regions.

The benefit of this effort was that the Space Shuttle was validated for critical Air Force missions and the requirement for additional thermal protection material substantiated by wind tunnel data which was generated by the Air Force. With the required material retrofits to be made later in the initial flight test program, the Space Shuttle will perform as required for Air Force missions.

Richard D. Neumann, AFWAL/FIMG, 513-255-5419



NAVIER-STOKES NOZZLE COMPUTATION

The increased importance of the aft-end drag problem associated with nozzle installations in current and future high performance aircraft has led to extensive and very costly experimental nozzle test programs. Computational aerodynamics shows great promise as a field which can have a favorable impact on this requirement for nozzle testing. It has been shown that boundary layer and shear layer growth, flow separation, shock formation and reflection, and plume blockage and entrainment characteristics of nozzle flows can be analyzed using computational techniques. Since computational costs are decreasing as more advanced computers are developed while experimental costs are steadily increasing, computational analysis is being investigated in much more detail.

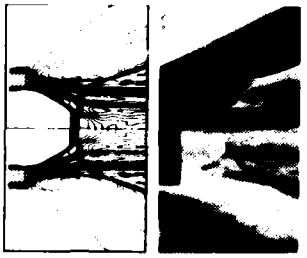
This Flight Dynamics Laboratory project consisted of numerically solving the complete Navier-Stokes equations for a domain containing an axisymmetric nozzle in a supersonic external stream (M_∞ = 1.94, M_{jet} = 3.0). Five nozzle pressure ratio conditions, ranging from a highly over-expanded case which exhibits a Mach disc shock formation to a slightly underexpanded case, were examined and solved numerically. As shown in the accompanying figure, both the complex shock wave structure and the viscous effects were accurately reproduced by the numerical technique. Computational values of the nozzle base pressure, in direct relation to aft-end drag, were in good agreement with the experimental data.

This is the first full Navier-Stokes computation that has accurately simulated the viscous-inviscid interactions present in an axisymmetric nozzle at off-design conditions where the strong Mach disc shock structure is present. This technical accomplishment demonstrates that numerical solutions can be extremely useful in investigating nozzle performance and the aft-end drag problem.

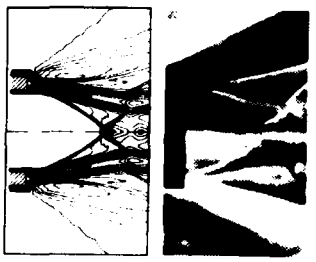
Capt. Gerald A. Hasen, AFWAL/FIMM, 513-255-2455

COMPUTATIONAL NOZZLE SOLUTIONS

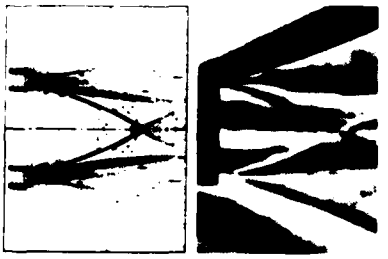
(COMPUTED MACH NUMBER CONTOURS VS SCHLIEREN PHOTOGRAPHS)



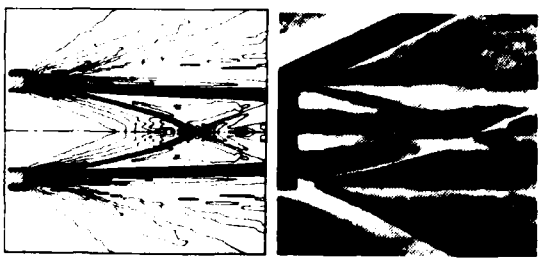
P_j/P_∞ = 0.15



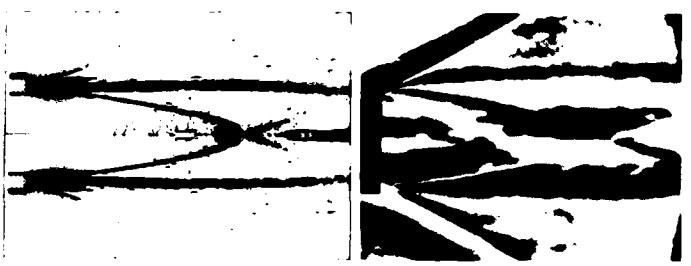
P_j/P_∞ = 0.25



P_j/P_∞ = 0.53



P_j/P_∞ = 1.03



P_j/P_∞ = 1.59

KC-135 WINGLET

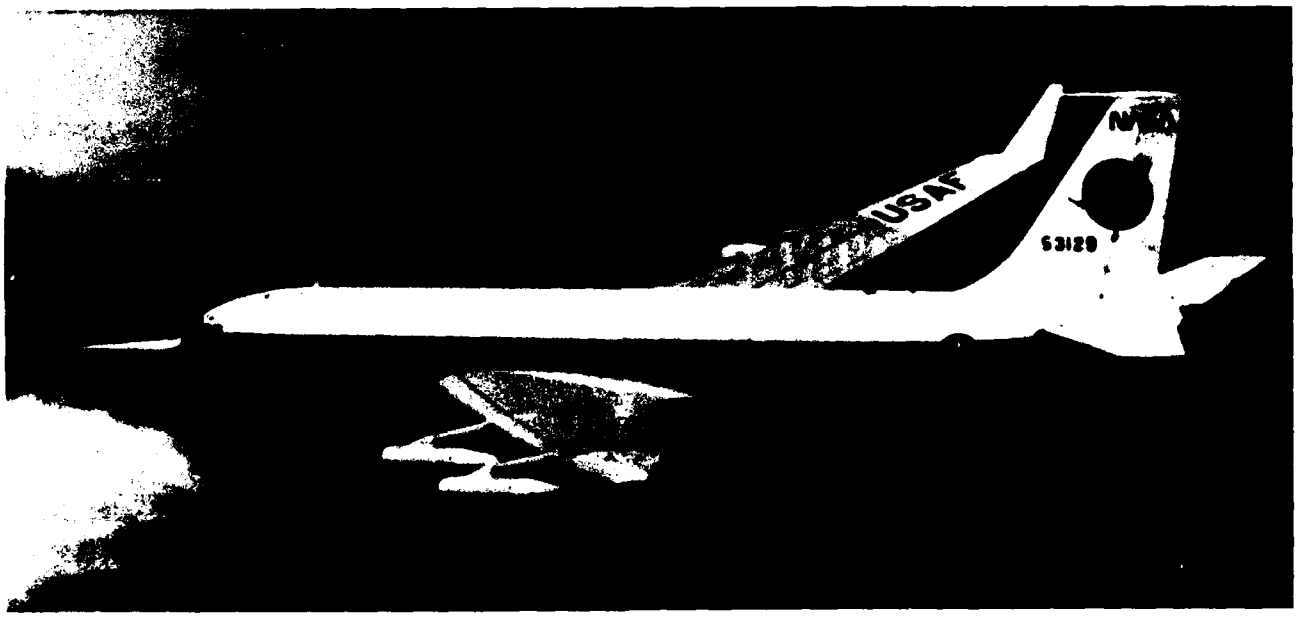
For the past several years, fuel costs have been increasing at unprecedented rates. To counter this problem, the Flight Dynamics Laboratory recently completed a joint Air Force/NASA research program aimed at demonstrating and quantifying fuel conservation due to winglet technology.

The flight phase of the KC-135 Winglet Program was completed with a total of 55 flights incorporating three winglet configurations. Flight test data demonstrated a 5-7% drag reduction and a 5-6% fuel savings, which translate into 24 million gallons of fuel saved per year based on current utilization rates.

A final symposium was held at NASA/Dryden Flight Research in September 1981. The symposium papers will be released as a NASA Contractor Report. AFWAL-TR-81-3115, "KC-135 Winglet Program," documents the analytical, experimental, and flight test results.

Winglet technology has transitioned to several military and civilian applications. Two of three CX proposals incorporated the winglet. The winglet is installed on Gates-Lear-50 series, Citation III, Westwind II, and Gulfstream II aircraft. In addition, the winglet is being flight tested for possible retrofit on DC-10 series aircraft.

David R. Selegan, AFWAL/FIMS, 513-255-6789



AFTI/F-16 FLIGHT CONTROL DIGITAL COMPUTER

A Flight Dynamics Laboratory program will soon give pilots of the future a "new way to fly". Using both conventional and decoupled flight control modes, involving direct force control and weapon line pointing, future pilots will have the capability to fly unconventional maneuvers which were previously impossible.

The Advanced Fighter Technology Integration/F-16 program, a joint program involving the USAF, Navy, and NASA, has developed an advanced digital flight control system for installation in the AFTI/F-16 demonstrator aircraft. Three digital computers form the core of the AFTI/F-16 triply redundant flight control system and, when combined with advanced redundancy management techniques that provide essentially two fail-operate capability, provide a loss of control capability of 1×10^{-7} failures per flight hour. The computers contain hardware logic which is used in fault isolation, identification, and inflight self-testing. In addition, they offer the advantages of decreased cost of ownership, reduced volume, and enhanced system performance.

The AFTI/F-16 program conducted its first man-in-the-loop simulation of the Automatic Maneuvering Attack System (AMAS). The simulator arrangement included a software model guidance system, a programmable software head-up display, and the AFTI/F-16 cockpit with computer generated visual system. The simulation modeling included the latest block design for the flight control laws, the full AFTI/F-16 nonlinear aerodynamics, and the Westinghouse sensor/tracker. Mission attack profiles were flown for air-to-air gunnery, strafing, and curvilinear bombing.

This first dynamic simulation of the AMAS weapon delivery options, flight control steering modes, and display format represents a significant systems design accomplishment. Observations and data indicated that the air-to-air tracking systems yielded a significant increase in effective tracking time on target when operated in an automatic steering mode versus a manual mode. Good results were also obtained in evaluation of the fully automatic curvilinear strafing and bombing modes. The pilots agreed that the system could best be used during air-to-ground encounter to increase situation awareness time by reducing pilot workload.

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SECTION IV
MATERIALS LABORATORY

AIR FORCE SUPPORT TO THE NATO/AGARD "CRITICALLY STRESSED HOLE TECHNOLOGY PROGRAM"

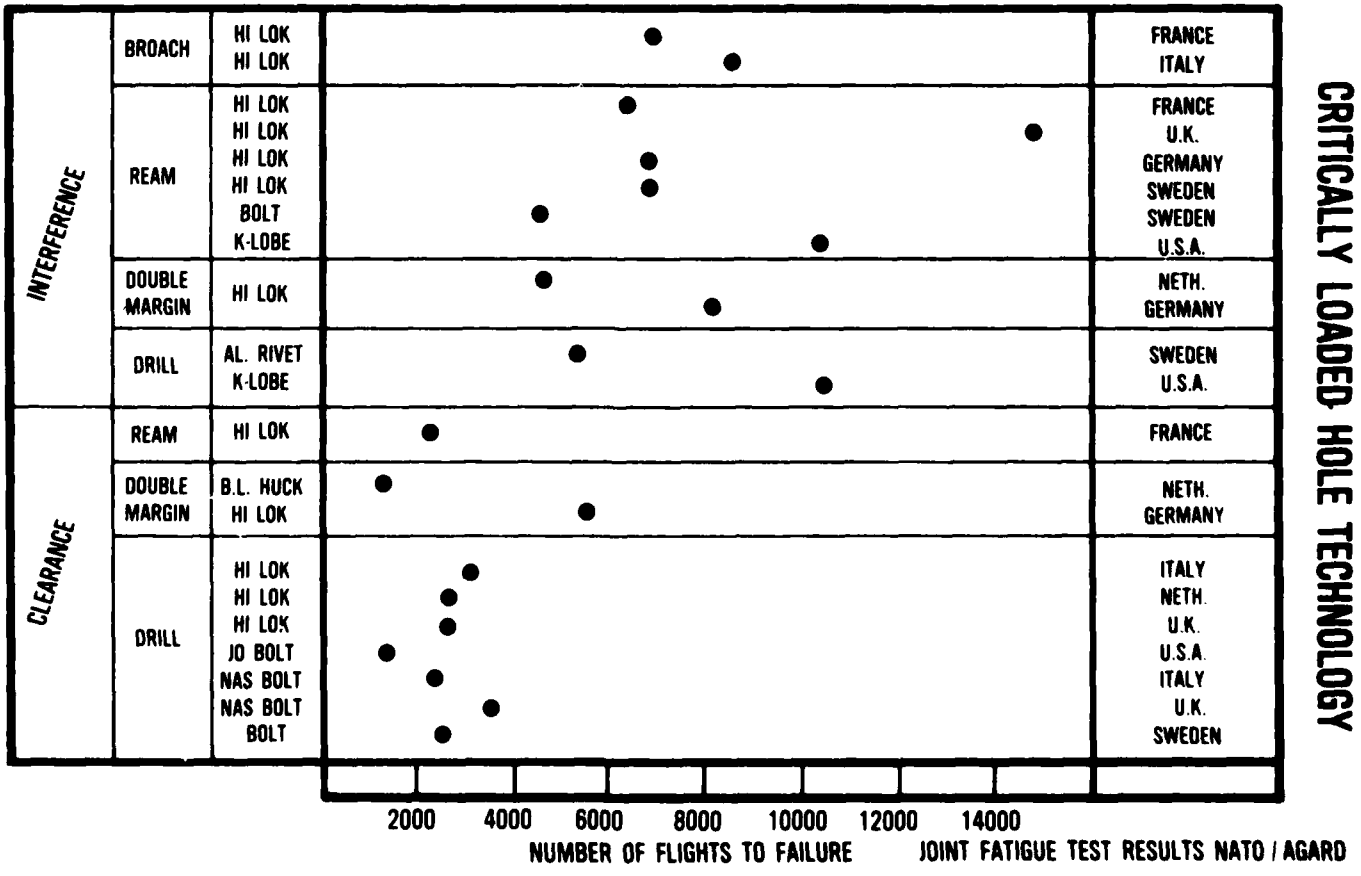
Substantial costs are involved in the procurement, installation, inspection, and maintenance of fatigue rated fastener systems in high performance military aircraft. In addition to high initial installation/assembly costs, fastening systems account for a disproportionate number of structural failures experienced by the operational aircraft fleet.

Because of the international nature of this concern, NATO/Advisory Group for Aerospace Research and Development (AGARD) panel was formed to specifically deal with the influence of hole quality and subsequent fastener installation on the initiation and propagation of mechanical fatigue in mechanically fastened joints. The Materials Laboratory was selected by the Air Force to outline this country's proposal for such a cooperative effort.

The Air Force proposal, in competition with similar proposals from other nations, was unanimously selected. The program investigated the interaction of fastener hole quality and resulting fatigue lives of low load transfer structural joints utilizing fatigue rated and non-fatigue rated fastener systems which were primarily loaded in shear. The highlight of the technical effort was the load level verification phase which established that there were few differences, within the range of testing frequencies, in the accuracy of loading or comparability of data among the member nation participants. The load verification phase utilized equipment specifically designed by the Materials Laboratory which added credence to the program and contributed greatly to its mutual acceptance. It was also determined that interference fit fasteners may be relatively insensitive to effects of surface finish and hole quality with the exception of dimensional tolerance. Reducing fastener hole quality while still maintaining structural integrity has significant cost savings implications.

The impact of this effort has been truly international in nature. One country has changed its manufacturing processes for highly stressed holes to eliminate a costly but ineffective broaching process. All participating countries have been able to improve their spectrum fatigue testing methods by using the load analyzation/verification data which became available.

Robert B. Urzi, AFWAL/MLSA, 513-255-5128

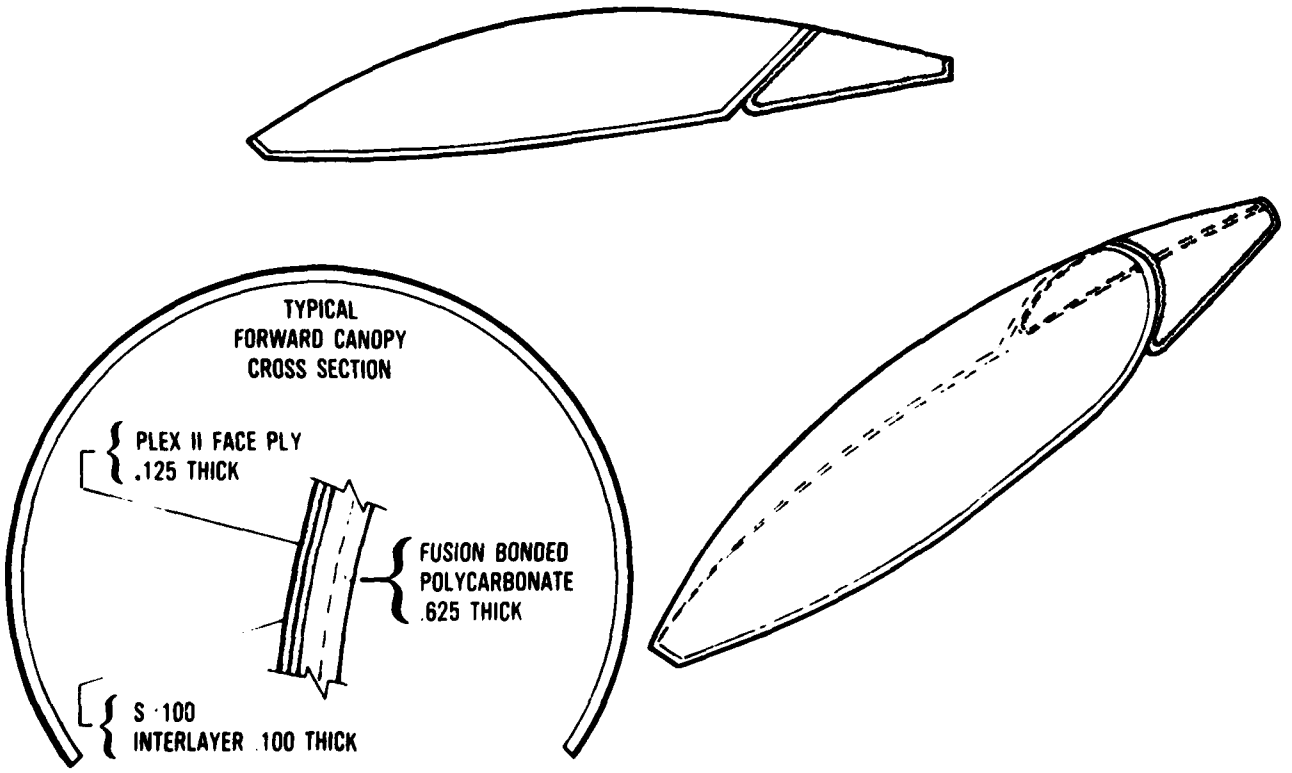


F-16 LAMINATED CANOPY

The F-16 canopy consists of fusion-bonded one-piece monolithic polycarbonate having a thin polymeric protective coating on the external and internal surfaces. Materials Laboratory and the F-16 SPO recognized that this approach entailed a certain degree of risk. Consequently, a manufacturing methods program was initiated to develop a laminated configuration concept as a back-up to the monolithic coated polycarbonate F-16 canopy. The objective of the contractual effort was to establish cost effective manufacturing processes, tooling, and inspection procedures for producing a compound curvature, laminated one-piece canopy meeting all F-16 canopy specification requirements. A service proven protective acrylic outer face-ply was used bonded with an interlayer to the fusion-bonded polycarbonate structural inner-ply.

The very large surface area, the complex wrap-around curvature of the F-16 canopy, and the stringent optical requirements precluded the use of any known state of the art processes. A manufacturing methods effort was completely successful in establishing a laminate-and-then-form process including control limits on the materials and process conditions required to produce acceptable laminated F-16 canopies. Most importantly, a versatile tooling concept was established which permits a range of laminate thickness selection and precise control of laminate cross-section reduction during stretch formulation with resultant outstanding optical properties in the final curved configuration. The availability of this proven manufacturing process and continued service-life problems with the coated polycarbonate F-16 canopy has resulted in recent production awards for initial GFE purchase of F-16 laminated canopies. Based upon extensive service performance experience of acrylic canopies in other aircraft, it is expected that a many-fold increase in service life will be obtained for the acrylic faced polycarbonate F-16 canopies, with a very significant savings in life-cycle cost of $175 million for the Air Force's entire 1,388 plane buy.

Sidney Litvak, AFWAL/MLTN, 513-255-7361



ADHESIVELY SEALED FUEL TANKS

At the request of the Air Force Logistics Command's (AFLC) Acquisition Logistics Division, the Materials Laboratory has adapted for use on modern aircraft the Scotchweld® adhesive sealing system, designated AF-10, which was used on F-102s and F-106s built in the 1950s. These older fighters' fuel tanks have required so little maintenance that repair costs are a fraction of those for newer aircraft, which have the polysulfide, rubber-like sealants in their tanks.

The challenge was to show that this sealing system could be adapted to the way aircraft systems are designed and built today and that it would be accomplished for the same or less initial cost than the competing polysulfide systems.

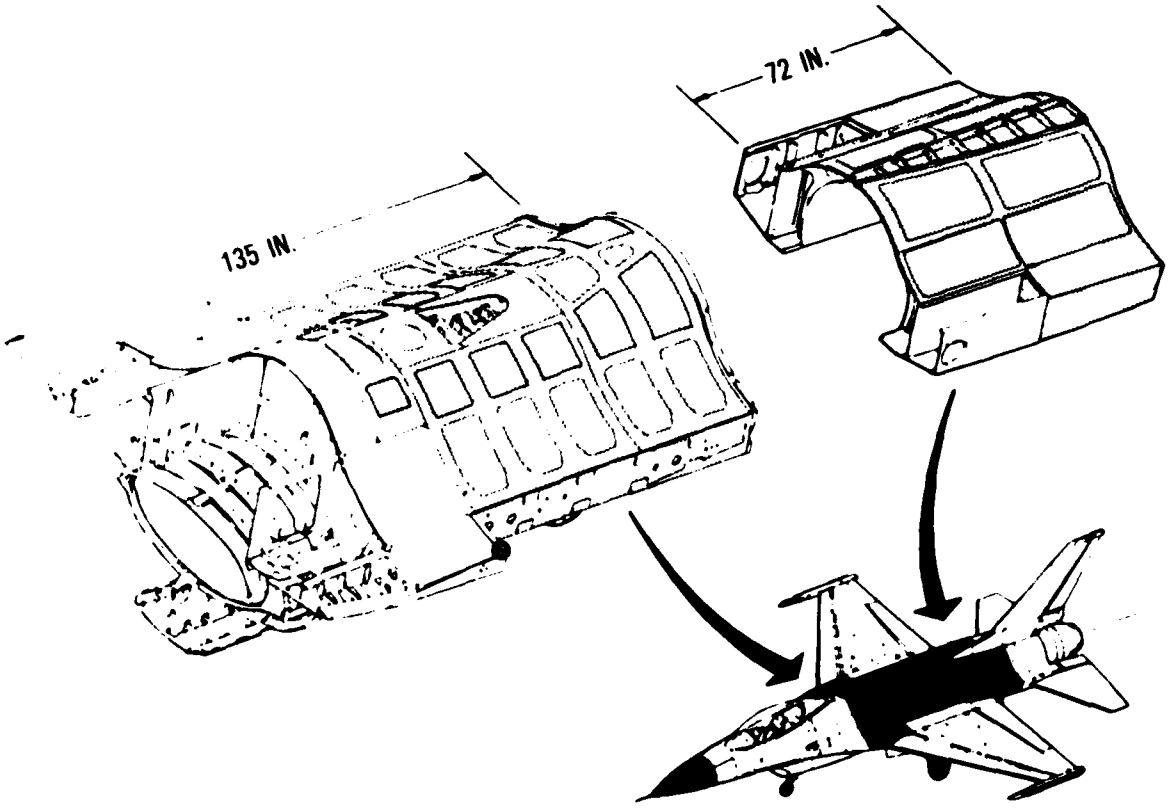
Under a program managed by the Materials Laboratory, General Dynamics, Ft. Worth, Texas, adapted the AF-10 sealant system to the center and aft F-16A fuselage tank sections which have more complex and curved structures than the F-102 and F-106 wing fuel tanks. It was learned that the AF-10 adhesive sealing system is compatible with the relaxed matched-up tolerances allowed in modern aircraft like the F-16. The tanks were built to F-16A design specifications in the normal production area using production personnel, fixtures, and equipment. Both sections successfully withstood the standard, specified F-16 air pressure test of five pounds per square inch. Because of that success, both tanks will be incorporated into a production F-16A scheduled for delivery to Edwards Air Force Base later this year for a special flight test program.

Final cost analysis figures on the program have been released and show that the manufacturing procedures developed under the program resulted in a Scotchweld® sealing process that is 25 to 40 percent more economical than polysulfide sealing.

AFLC has selected this sealing system for its C-130 wing mod program which began in April 1981, and is promoting its use in future acquisition programs. Four hundred and ninety-five shipsets of new wings for retrofit on older model C-130s will be built. The program is being conducted by Warner Robins Air Logistics Center and Lockheed-Georgia Company, Marietta, Georgia.

Sidney Litvak, AFWAL/MLTN, 513-255-7361

F-16 CENTER AND AFT FUSELAGE TANKS



MACHINE TOOL TASK FORCE

The most comprehensive study of machine tool technology ever undertaken in the United States has just been completed by the International Machine Tool Task Force (MTTF) as a result of a 30-month project sponsored by the Materials Laboratory and performed by Lawrence Livermore Laboratory. The program results were presented at a conference held in Chicago, Illinois, for 700 attendees from industry, academic, and government sectors. A comprehensive 5-volume report provides the primary documentation for the project, which studied and assessed the international state of the art in this field and established the basis for follow-up planning on technology development and institutional change in this area of fundamental economic importance. Technical scope of the MTTF covered machine tool mechanics, controls and accuracy, and systems management and utilization. Highlights of the Conference included major addresses by Dr. Arden L. Bement (USDRE/R&AT) and Mr. Rueben J. Jensen (Executive Vice President, General Motors Corporation). Heavy coverage in the technical press was evident, including a special issue of American Machinist, issued coincident with the conference, which devoted 23 pages to its analysis of the MTTF project. It summarized its findings as follows: "from 30 months of work comes a remarkable report on current technology, trends, and directions for R&D. It will be debated . . . and mined for information . . . for years." The 5-volume reports are available from the National Technical Information Service, under report number UCRL 52960—1,2,3,4,5.

Rosann Stach, AFWAL/MLTM, 513-255-2413

ISOTHERMAL FORGING OF F100 BLADES

Material and energy savings and increased productivity were goals of isothermal forging of F100 blades. The process was demonstrated by TRW, Inc. by the production of more than 300 F100 engine first stage fan blades. A substantial data base was established in blade dimensional reproducibility and metallurgical quality, forging lubricant and die performance, and process cost savings. Excellent blade airfoil dimensional reproducibility of ±.003 inch for the isothermal forging process was established. Despite the Ti-8Al-1Mo-1V component alloy's extreme resistance to being forged conventionally, completely adequate metallurgical quality resulted from isothermal processing. Isothermal forging of other titanium alloy blades, such as Ti-6Al-4V, would, therefore, be even more easily adaptable to the process. Excellent performance was obtained from the relatively low cost IN-100 forging dies by advanced application of CAD/CAM die design and manufacture. Adequate die and lubricant elevated temperature capabilities were demonstrated in an exceedingly harsh forging environment of 1760°F. This net shape technology has shown that isothermal forging is material and energy efficient and is also amenable to a high productivity processing sequence. The buy-to-fly ratio is 1.83 for the program component, which accomplished a materials savings in excess of three pounds per blade over the present production method. Material, energy, and productivity improvements should result in a 20-percent cost savings for the program component.

Robert J. Ondercin, AFWAL/MLTM, 513-255-2413

COMPOSITE SKIN STABILIZATION

Recent development efforts sponsored by the Materials Laboratory, coupled with industry sponsored independent research, have established the feasibility of composite skin stabilization techniques with improved durability and maintainability as alternatives to full-depth aluminum honeycomb structures. It logically followed as a next step to demonstrate and validate low cost and innovative skin stabilization manufacturing methods for composite secondary structure that is cost competitive with full-depth honeycomb structure.

Under contract to the Materials Laboratory, Grumman Aerospace Corporation demonstrated an alternative to metallic honeycomb structures. A simulated production run of two full size F-111 horizontal stabilizer trailing edge assemblies utilized an innovative design/manufacturing approach optimized for producibility and low cost. The selected component is an existing large area (14.2 square feet) aluminum honeycomb sandwich design for which considerable data are available. Also, because of its long service life on the F-111, significant maintenance experience exists.

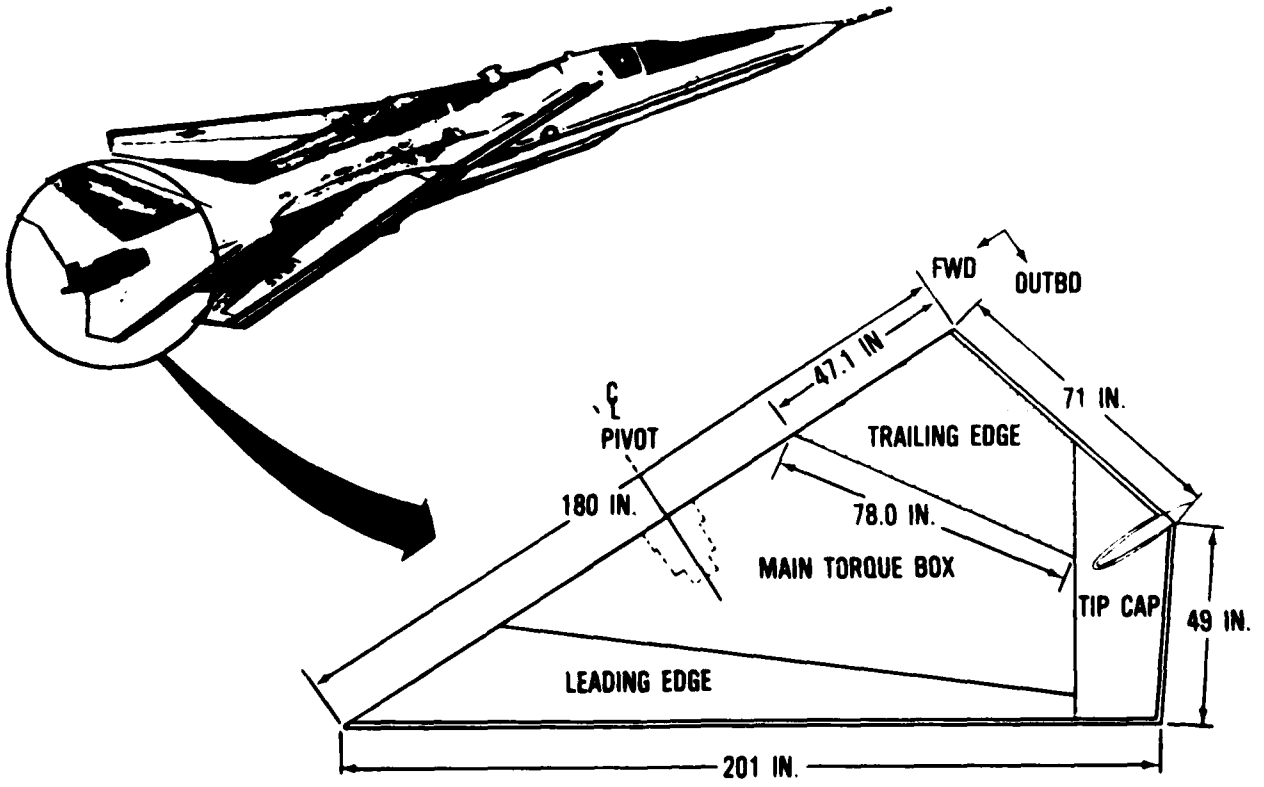
Production level quality control/non-destructive evaluation and cost tracking procedures were implemented for each of the two articles produced. All manufacturing work was performed in a production environment at the production organization with a complete set of production tooling.

A cost and producibility analysis showed that the composite replacement structure was 14 percent lighter and 21 percent lower in production acquisition costs. Analyses project a minimum life cycle cost savings of 53 percent. Based on the results of this program, the Sacramento Air Logistic Center initiated extensive flight service evaluation of the parts produced on this program on operational aircraft. Repair procedures have been prepared, suitable for base or depot level maintenance, in the event that damage does occur during flight service evaluation.

On new acquisition aircraft, the cost and weight benefits demonstrated by this concept of skin stabilized composite structure should be very attractive.

Harry S. Reinert, Jr., AFWAL/MLTN, 513-255-7277

EF-111A HORIZONTAL STABILIZER TRAILING EDGE (LEFT HAND)



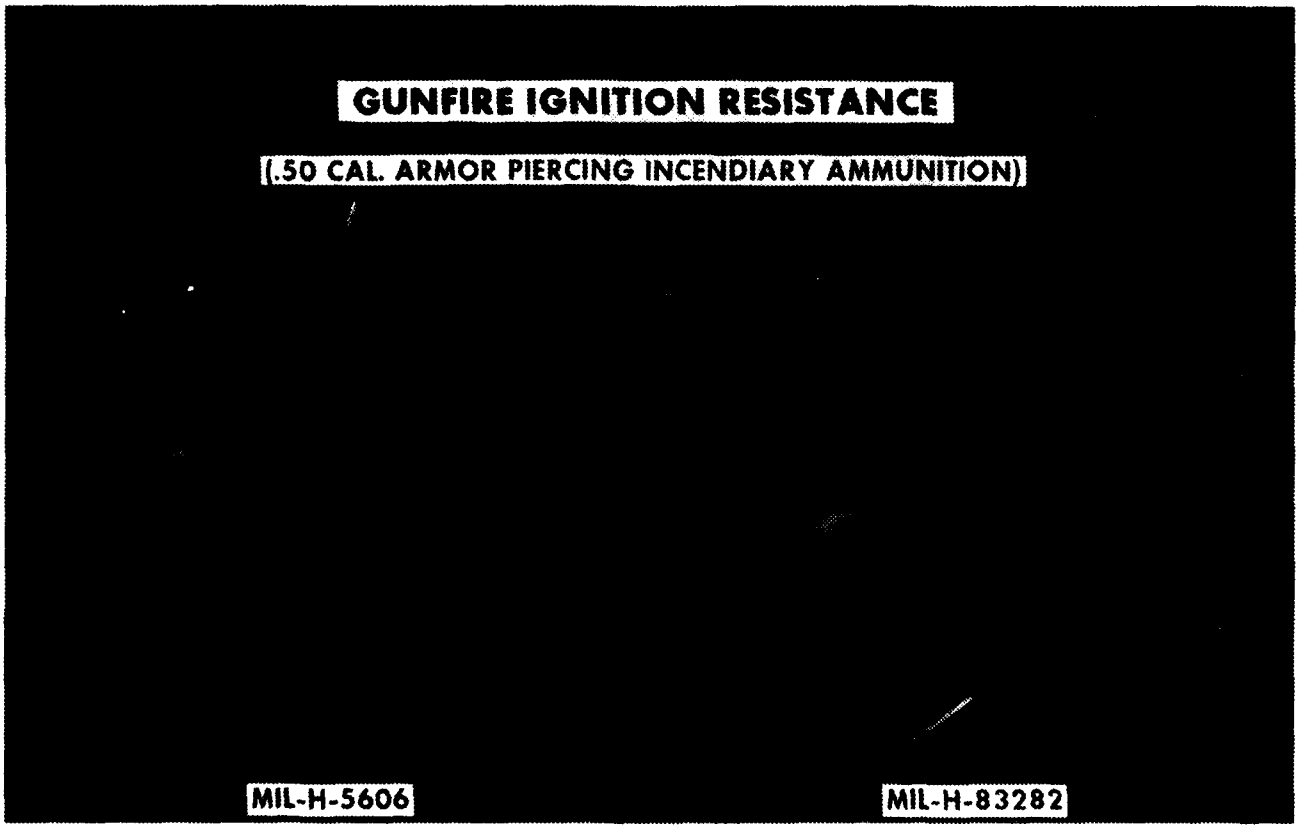
MIL-H-83282—FIRE RESISTANT HYDRAULIC FLUID FOR AEROSPACE APPLICATIONS

The successful development of MIL-H-83282 by the Materials Laboratory provided by the Air Force with a fire-resistant hydraulic fluid for application in current aircraft. This hydraulic fluid, which has significantly improved fire resistance over the previous standard hydraulic fluid, MIL-H-5606, has recently been adopted for use as a direct replacement requiring no component retrofit, in all Air Force aircraft which have transitioned to the Air Force Logistics Command except the B-52, KC-135, and the few aircraft designed to use phosphate ester hydraulic fluids. In addition to the significant reductions in aircraft lost or damaged as a result of hydraulic fluid fires (>100 million between 1970 and 1975) anticipated by converting the fleet to MIL-H-83282, its improved lubricity and shear stability over MIL-H-5606 will result in improved hydraulic system performance and longer component life. These advantages will result in significant, but difficult to document, cost savings from aircraft maintenance and reliability aspects.

In addition to utilization in Air Force aircraft, MIL-H-83282 has been adopted by the Army and Navy for use in their aircraft and is used in NASA's Space Shuttle. The addition of a rust inhibitor to MIL-H-83282 resulted in the development of MIL-H-46170, another fire resistant hydraulic fluid which has been adopted for use by the Army in their ground vehicles (e.g., the M-1 and M-60 battle tanks). MIL-H-83282 has been selected as the hydraulic fluid in the Navy's experimental high pressure (8000 psi) aircraft hydraulic system advanced development program.

The synthetic hydrocarbon chemistry developed for this hydraulic fluid development program has provided spin-off in the civilian sector in the area of synthetic based crankcase oils for the automotive industry.

Carl E. Snyder, AFWAL/MLBT, 513-255-5731



AIRCRAFT MANUFACTURING QUALITY ASSURANCE USING PHOTOGRAMMETRIC TECHNIQUES

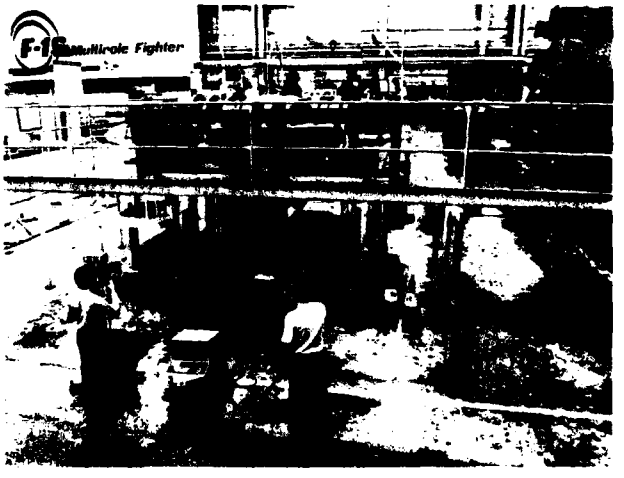
Historically, the aircraft industry has controlled the dimensional integrity of major aircraft component assembly tools by means of component master gages (COMG). Periodically, the COMG, which is used in manufacturing the tool, is reinstalled to assure fidelity to the original configuration—a process called periodic inspection (PI). In addition to the labor required for the PI, there are penalties of production downtime and lost productivity. Photogrammetric techniques verify the tool alignment with little or no production downtime and 1/4 to 1/10 the cost of conventional PI. Theodolite techniques are used to supplement photography for establishing metrology baselines and for areas requiring greater accuracy.

General Dynamics, Fort Worth Division, under contract to the Materials Laboratory, has established the use of photogrammetric metrology for routine assembly tool alignment verification.

The program was conducted in three evaluation phases. The first was to establish the utility and cost effectiveness of the photogrammetric technology as applied to complex tools. The second phase was a component assembly coordination study which employed stereo photogrammetric techniques. The final phase evaluated the parameters for use of photogrammetry for very large aircraft tooling.

Photogrammetric PI has now been implemented on 36 assembly tools, of eight families, for the F-16. These include complex assemblies such as the center fuselage and aft fuselage. As of September 1981, photogrammetric PI has been accomplished 38 times on various tools with a cost savings of $120,732.06. It is estimated that the cost avoidance using photogrammetry during the F-16 production program will total $2.5 million.

Edward Wheeler, AFWAL/MLTM, 513-255-2413



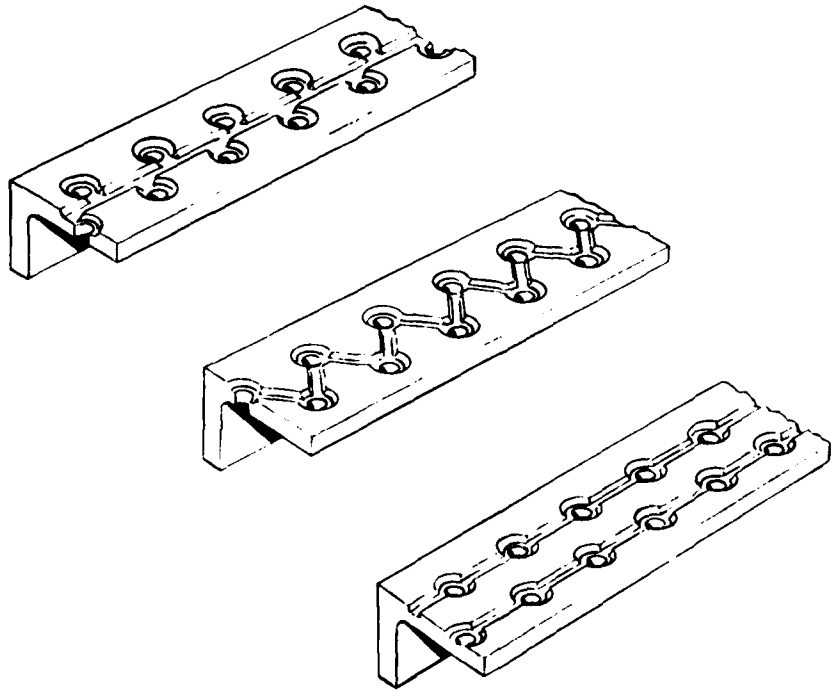
INTEGRAL FUEL TANK CHANNEL SEALANT

he efficient use of space on board military aircraft ıires that many odd and irregularly shaped cavities sed to carry fuel. Some cavities are large enough to ïitted with bladder type fuel cells, but a greater ıme of fuel can be contained when the aircraft skin structural members become the walls of the tank. method of sealing the skin and structure is called ınel sealing. A noncuring elastomeric sealant is in-:d through ports in the skin into grooves prepared in ;tructural members. Successive injections transform :tion of the aircraft into an integral tank. The most ortant advantage of channel sealants over other ant approaches is the ease of repair. The channel ant in a leak area can be replaced by injecting new ant into the groove from outside of the aircraft. :e defueling, removal of sealant, surface cleaning, curing of the new sealant are eliminated, the air-t can be operational in 30 minutes in contrast to as :h as 3-5 days for other sealant methods. Unfor-ıtely, leak problems have been experienced with ınel sealants where structural tolerance buildup :e gaps or mating surface mismatches.

he Materials Laboratory began an in-house ;ram in 1975 to determine the environment of fuel tank, establish mechanisms of sealant failure, and to develop improved materials that would overcome as many of the failure mechanisms as possible with a balance that would maximize the service life. Of the sealants considered, non-curing fluorosilicone containing cross-linked fluorosilicone particles was selected. This channel sealant is now being flight tested at Eglin Air Force Base under a test program funded by the PRAM Office. Five F-4 aircraft were retrofitted with the new sealant in one wing fold area while the other wing fold area was reinjected with the currently used material. The wing fold area on F-4's is particularly prone to fuel leakage. The test aircraft are being flown and tracked for three years to provide a direct comparison between the two materials under actual service conditions. In addition to the flight test, one aircraft was subjected to a five-day cold soak at $-65°$ in the climatic hangar. In this evaluation of cold weather performance, no leaks occurred in the resealed areas. As the success of this new sealant continues, it will be added to other fuel tank problem areas of the F-4.

Warren R. Griffin, AFWAL/MLBT, 513-255-5375
William F. Anspach, AFWAL/MLBT, 513-255-5375

TYPICAL GROOVES IN STRUCTURAL MEMBERS



COMPOSITE SKIN FABRICATION

The Materials Laboratory recognized the desirability of finding alternatives to full-depth honeycomb metallic structures that are more durable and lower in life cycle cost. A manufacturing methods program was initiated at Vought Corporation, Dallas, Texas, to establish and validate a low-cost innovative manufacturing method for producing skin-stabilized composite structures which are cost and weight competitive with full-depth honeycomb metallic structure. In addition, shop floor production personnel produced ten T-38 aileron trailing edges that will be installed on Air Force aircraft to obtain in-service data on the durability of the composite structure.

The manufacturing method incorporates a non-autoclave cure processing technique and integral curing of the skins and substructure. The required cure pressure is provided and controlled by use of an elastomeric bladder tool. Detailed cost tracking during production of the ten trailing edges provided valuable insight into the high cost areas of composite production. Learning curves developed from the cost tracking data were used to verify that the composite components are cost competitive with conventional metal honeycomb components in volume production. A repair manual for the composite skin-stabilized trailing edge wedge was prepared that specifies the structure as well as damage criticality for Air Logistics Center needs.

The Air Logistics Center has purchased an additional 20 trailing edges, which will be used along with the original ten, in a service evaluation program. The manufacturing methods program has provided a viable cost-competitive alternative to the currently used honeycomb structure.

Harry S. Reinert, AFWAL/MLTN, 513-255-7277

COATINGS FOR SPACECRAFT CHARGING CONTROL

Anomalous spacecraft operation due to electrical charge build-up and subsequent discharge is a problem when operating in the synchronous earth orbit environment. These discharges may cause disruptions or even catastrophic damage to electronic components as well as degradation of thermal control materials. Charge control is of special concern for future systems with expected service lives of seven to ten years.

Thin coatings of indium tin oxide (ITO) and indium oxide (IO) have been shown to be space stable, with low electrical resistance and solar absorptance. Efforts to reproducibly deposit these coatings on typical thermal control materials have also been successful. The development and evaluation by the Materials Laboratory of ITO and IO coatings have generated a great deal of confidence in their charge control ability and have established the processing parameters required to achieve a conductive, yet high transmittance, coating.

Coating thicknesses between 100Å and 1000Å have been explored to determine the optimal value. Storage, handling, and environmental testing indicate that 200Å coatings can be reproducibly deposited and provide highly stable semi-conducting properties with solar absorptances of one or two percent. The coatings, when applied to glass, FEP Teflon, and Kapton, have consistently yielded resistance values in the low kilo ohm/square range.

The charge control characteristics of the coatings have been evaluated under simulated substorm conditions. Measurements of surface potentials during and after irradiation by electrons up to 25 kev shows an effectively grounded surface with no evidence of charge build-up or discharging. Discharges were also not observed on samples which had previously been exposed to heat, humidity, chemical spray, and thermal cycling tests before electron irradiation. The programs conducted by the Materials Laboratory have yielded innovative charge control techniques for critical satellite systems.

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ELECTRICAL AND OPTICAL CHARACTERISTICS OF 90% In_2O_3 / 10% SnO_2 (ITO) COATED KAPTON (2 mil)

ITO THICKNESS (Å)	SURFACE RESISTIVITY KΩ /□	(VISIBLE) TRANSMISSION	OPTICAL CONSTANTS		
			α	ε	RATIO α/ε
900	.45 - .75	56.6	.311	.546	.569
900	.45 - .75	53.1	.297	.583	.509
500	3 - 7	59.4	.276	.565	.488
500	3 - 7	58.7	.274	.559	.490
250	80 - 150	59.9	.293	.538	.540
250	80 - 150	59.9	.284	.540	.548
UNCOATED	10^{14}	60.06	.284	.539	.524

CARBON-CARBON COMPOSITES FOR MISSILES

Carbon-carbon composites are newly developed high temperature structural materials currently being used for a number of critical aerospace applications. Advanced missile reentry systems use carbon-carbon composites for shape-stable nose tips. Carbon-carbon is used for the Space Shuttle's nose cap and leading edges. Large solid-propellant rocket motors will use these advanced composites in the integrated throat and entrance (ITE) section of the nozzle, such as the 500-lb ITE for the first stage of the MX missile.

The carbon-carbon composites are composed of a graphite matrix reinforced with graphite fibers in a three-dimensional array. They were first fabricated under the Materials Laboratory sponsorship in 1967. The Laboratory continued to develop the composites with the Air Force Ballistic Missile Office subsequently entering advanced development with these new materials.

The new carbon-carbon missile nose tip has one-half the thermal recession of a carbon-phenolic nose tip and excellent shape stability during missile reentry, thus providing increased accuracy and enhanced survivability. The material is now used on the Minuteman III Mark 12A reentry vehicle, and it is being used to replace the nose tip material presently on the Mark 12.

The carbon-carbon composites are uniquely suited to the extreme environments encountered at the nozzle throat. Their low erosion and high durability in hot propellant gases permits highly reliable and lightweight nozzles for solid propellant motors. The carbon-carbon composites provide highly promising solutions for MX and Trident II nozzle throats. All three MX propulsion stage contractors are using one-piece carbon-carbon nozzles in the full scale engineering development program.

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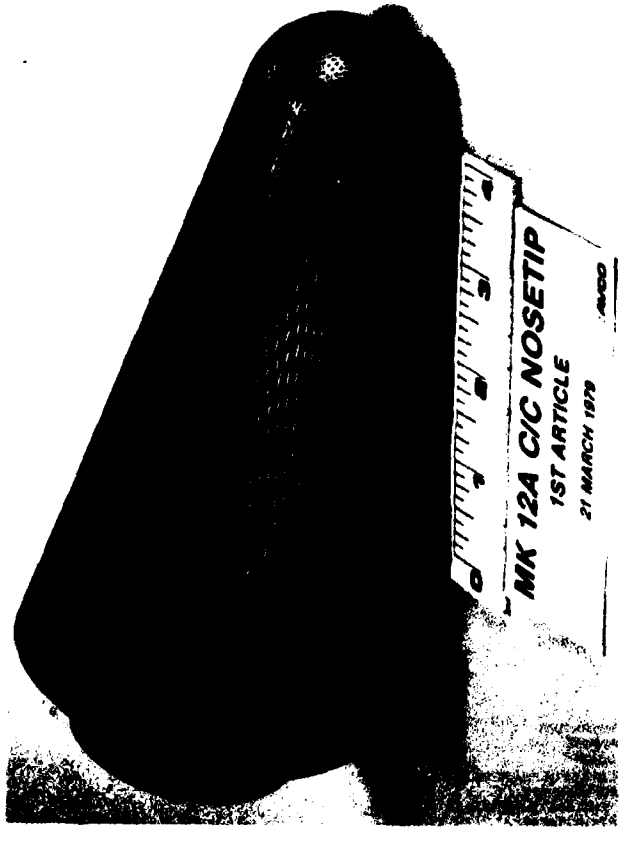

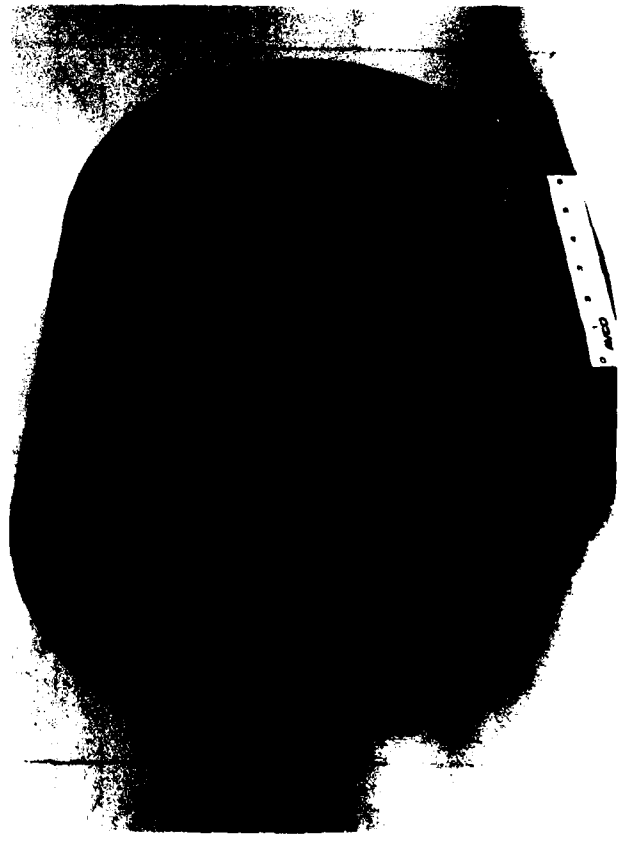

ADVANCED COMPOSITES IN-PROCESS CONTROL/INSPECTION

Composite structures are being used in all new aircraft/aerospace vehicles at an ever increasing rate. Quality control and tracking of the materials and processes used to manufacture these composite parts are critical. The Materials Laboratory managed a program, conducted by General Dynamics, Ft. Worth, Texas, that has established and demonstrated an integrated system of quality control and inspection for tracking composite aircraft structures through a production manufacturing facility. The semi-automated and computerized processes that were established and validated are: (1) prepreg analysis system, (2) tape laying inspection system, (3) cure control system for the autoclave, and (4) laminate nondestructive inspection (NDI) station. Methods of module coding and automatic recognition for stacking were also demonstrated. The systems not only provide improved quality control and reduced cost, but, coupled to a central data computer, also provide for complete detailed tracking of all of the key elements and materials of composite part manufacturing.

The systems for quality control and tracking are now being installed for the F-16 production line. Further verification of the success of this program is the estimated $5.45 million inspection, control, and material savings over the remainder of the F-16 program. A portion of these savings has already been reflected in near term F-16 acquisition by agreement between General Dynamics and the F-16 System Programs Office.

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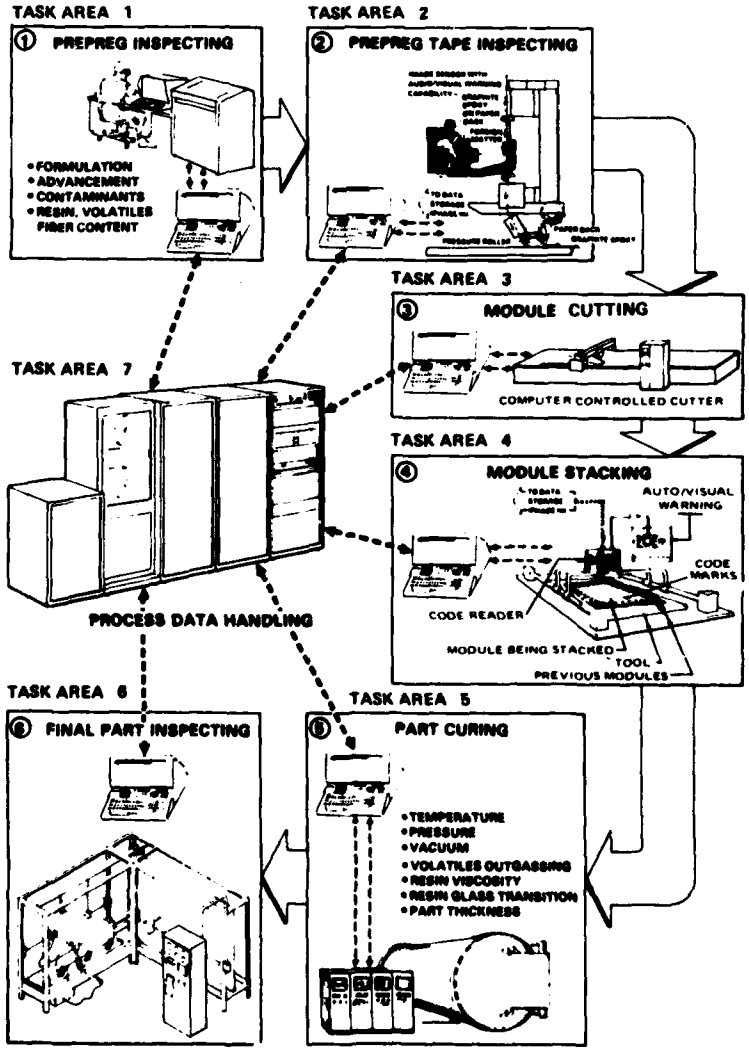

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